Geological Fieldwork: A Study Carried Out With Portuguese Secondary School Students

Helena Esteves,[1] Paulo Ferreira,[1] Clara Vasconcelos,[1,a] and Isabel Fernandes[1]

ABSTRACT

Recognizing the relevance that fieldwork and field trips have in the teaching of geosciences and related learning processes, this study presents two geological fieldwork studies that were established with Portuguese secondary school students. Both studies were focused on geoscience content knowledge, and attempted to increase environmental awareness and highlight geoheritage values. Following the Orion model (1993), the fieldwork was established in three stages (the preparatory unit, field trip, and summary unit), which facilitated its implementation and subsequent assessment. Both studies took place in regions in the north of Portugal. One field trip was undertaken at the coastal area of Vila do Conde and the other on the left bank of the Minho River, in Monção. Since a mixed methods research design was applied, different data types were collected and triangulated. Results indicate that the fieldwork was effective in terms of facilitating the development of conceptual knowledge, motivation, and diverse competencies. These results contribute to the recognition of fieldwork as an important strategy in geoscience education and geoscience awareness. The study also highlights that the relevance of fieldwork should be recognized by Portuguese curriculum designers and should be incorporated in the Portuguese science curriculum. © *2013 National Association of Geoscience Teachers*. [DOI: 10.5408/12-394.1]

Key words: fieldwork, field trip, geology, Portuguese students

INTRODUCTION

Fieldwork is a strategy with enormous potential, both for teachers and students in terms of developing competencies, aiding academic success, and promoting interdisciplinary and transdisciplinary learning. Fieldwork activities greatly enhance interdisciplinarity and a transversal content approach, both of which are referred to by didactical investigation as essential to science teaching. Under a constructivist perspective, these activities can be used as teaching strategies since they enable the consolidation of previously discussed concepts and promote development of specific competencies. In addition, these activities enable the understanding of more abstract concepts, which are generally harder for students to understand and more difficult to explain within the classroom. During a field trip, these concepts are directly observed in a real context, making their explanation easier and understanding more comprehensible (Ferreira, 2011; Ferreira et al., 2013). Geology teaching in Portuguese secondary schools is still very much based on theoretical presentations and memorization processes, and lacks experimental components and fieldwork. This has led to the effort of taking advantage of the best and most motivating geological laboratory: the field. To achieve this, it was necessary to investigate its potential and put it into use to aid the teaching and learning processes within the context of environmental education by creating materials and tools and applying motivation strategies (Esteves, 2011; Esteves et al., 2013).

In this study, two field trips were carried out, both in accordance with Orion's organizational model (Orion, 1993), one in the coastal area of northwest Portugal (Vila do Conde) and the other on the left bank of the Minho River, in the north of Portugal (Monção). Both field trip activities were planned for integrating place-based learning. The field trip to Vila do Conde comprised one itinerary with six study stations. During four of these stops, the suggested activities were related exclusively to the development of geological competencies, while the suggested activities in the other two stations were also directed at the development of environmental competencies, particularly those related to the exploitation and management of geological resources. The field trip to the left bank of the river Minho consisted of one itinerary with five study stations. The suggested activities were aimed at developing the students' competencies in the identification of lithological and geomorphological aspects. Students were also expected to be able to identify different aspects related to human occupation and its impacts on the evolution of the landscape, and detect natural and/or geological risk situations.

Both fieldwork activities were implemented in three stages: the preparatory unit, field trip, and summary unit. Specific didactical materials were created by relating curricular concepts to existing field resources in the areas surrounding the school. Other materials, such as geological and topographic maps, were also used.

In the first stage, the "novelty space" was reduced by providing students with geographic and scientific information about the fieldwork and explaining how it would be developed. Activities were prepared with the help of problem questions, as well as with the use of informative work sheets and PowerPoint multimedia presentations, which also helped to promote motivation. The one-day field trip activity was carried out in groups of five or six students. It conformed to a field guide that was supported by miniposters and followed a study station itinerary. The teachers elaborated on the miniposters in some study stations to better explain some geological processes that

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[1]Faculdade de Ciências da Universidade do Porto, Centro de Geologia da Universidade do Porto, Rua do Campo Alegre, 4169 007 Porto, Portugal
[a]Author to whom correspondence should be addressed. Electronic mail: csvascon@fc.up.pt. Tel.: +351 220 402 462. Fax: +351 220 402 490

were conceptually more demanding. In Orion's articles, miniposters are referred to as educational tools that enable teachers to better explain some geological processes that are more difficult to understand in the field. They are small and easy to transport in the field, and made by teachers with few words and many images.

The final stage was carried out within the classroom. It promoted reasoning, the consolidation of conceptual knowledge, and assessment of the activities. The teacher employed worksheets, PowerPoint presentations, and an evaluation test.

THEORETICAL FRAMEWORK

Fuller (2006), mentioning the work of Dando and Wiedel (1971), clarifies the concept of fieldwork as a strategy that can incorporate field teaching, field trips, field research, or even field camps. Learning geological field skills is generally believed to be one of the most important aspects in the education of a geoscience student. Unfortunately, factors such as time and money often restrict the incorporation of field components into every course curriculum (Benson, 2010). However, a decline in field experience represents a threat to the abilities of future generations to explore natural resources. As such, it is important and necessary to promote field activities so that geology can be learned through practice rather than solely from books, and geological heritage can be maintained (Van Loon, 2008). Fieldwork is a learning strategy directed at solving geological and environmental problems, particularly since ground materials and structures are better identified through observation than through a mere description of their characteristics. Moreover, current materials and structure associations may lead to the discovery of new relationships and features, thus promoting the construction of new concepts (Compton, 1985).

Marques and Praia (2009) refer to outdoor activities as strategies that favor a more effective involvement of students in the learning process, as well as collaborative work among students, and an improved relationship between them and the teacher. The authors also state that, given the complexity of interpreting the natural environment, appropriate methodologies should be sought, which requires the establishment of a dialogue between students under the mediation of the teacher. Moreover, they point out the potential of outdoor activities to accomplish science education goals, such as promoting a better understanding of natural processes and using scientific knowledge to effectively appreciate the natural environment.

Marques et al. (2003) promoted research designed to enhance the effectiveness of fieldwork activities by Portuguese teachers. This research demonstrates that teachers often fail to put theory into practice, which may result from a lack of confidence in the implementation of new procedures, and that students seem to enjoy both the social interaction with other students and the opportunity to work independently of teachers.

Orion (1993) emphasizes the relevance of an adequate preparation for a field trip, which reduces the novelty space to a minimum and thus facilitates meaningful learning processes during the field trip. Whatever the model used to promote fieldwork, if one wants to ensure its success then its adequate organization is clearly needed. According to Orion's model, the concepts to be learned in the field are classified according to their level of objectivity or abstraction (Orion, 1993, 2007). The appropriate time for teaching—before, during, or after the field trip—is also determined according to the level of abstraction. The required role of the teacher is to make it easy for students to have an active role in the field. However, the lack of related relevant educational materials often hinders the teachers' will to organize a field trip (Mirka, 1970; Hickman, 1976).

As stated by Fuller et al. (2003), students perceive fieldwork to be beneficial to their learning process, since it helps them to develop subject knowledge, acquire technical and transferable skills and to interact socially with their lecturers and peers. Orion and Hofstein (1994) refer to the lack of attention with which teaching in a field environment is looked upon, which reflect our limited knowledge and understanding of the field as an effective learning environment. Furthermore, the authors state that one of the reasons for this limited knowledge and understanding is the absence of a suitable technique for verification and evaluation. Accordingly, the authors recommend the development and implementation of inquiries to evaluate the activities developed during field trips. This assessment can help teachers and researchers to better understand the perceptions of students in these learning environments. Whatever the case, assessment of the field studies should always take place in an effort to improve the teaching and learning processes of geosciences (Lima et al., 2010).

METHODOLOGY

The research team chose an evaluation study as the appropriate methodology to be used. A mixed methods study design utilized different techniques and instruments, such us short questionnaires, lesson reports, and an inventory.

Sample

The study sample consisted of 280 secondary school geology students from three public schools in the north of Portugal, all attending 11th grade, with ages ranging from 15–19 (average age, 16 years). The students were distributed into 13 classes. The majority of participants were girls (n = 146; 52%).

All students participated in the fieldwork, a one-day geology field trip that was prepared and established according to the model suggested by Orion (1993). Although each class carried out all three fieldwork stages independent of the other classes, the model and type of educational materials that were used, both in the organization and implementation of the activities, were similar. All field studies were conducted as an integrated part of their secondary school geoscience curriculum.

The six science teachers that taught the students participating in the study had previous professional training on the Orion model and were aware of its precepts on how to organize field trips. They were also familiar with the geology education aspects of the areas studied. Two researchers (the first two authors of this article) taught the above-mentioned professional training course, and both were participant observers in all phases of all field studies.

TABLE I: Educational materials used in the field trip activities.

Field Trip Phases	Educational Materials
1. Preparatory unit	Teacher field guide and student field guide.
	Factsheets: rules and behaviors, geographical location of the study stations, itinerary, local geology, and characterization of the geological lithology along the itinerary.
	Worksheets: rock samples, and military and geological maps.
	PowerPoint multimedia presentations.
2. Field trip unit	Student field guide.
	Miniposters.
3. Summary unit	Student field guide.
	Worksheet: rock samples and dichotomous keys.
	PowerPoint multimedia presentations.

Educational Materials

Different educational materials were developed for each of the three phases of the field study activity: the Preparatory Unit, the Field Trip Unit, and the Summary Unit (Table I). These materials were prepared to help the teacher and students better explore the field as a didactic resource, as well as to promote the success of the learning outcomes, such as conceptual understanding, collaborative competencies, and problem-solving skills.

Another relevant aim of the educational materials was to guarantee the promotion of motivation and attentiveness during the field trip.

Evaluation Instruments

Different techniques and instruments were applied to both students and teachers in order to collect the data needed to evaluate the field studies. The six science teachers that taught the students participating in the study mediated the activities performed in the three phases of the field trip.

The evaluation instruments used in the different stages of the field study are presented in Table II. Some of these instruments were applied both to teachers and researchers. The others were applied to students.

The short questionnaires applied to students also included some open questions, the answers to which underwent content analysis. Those questions were formulated to evaluate the positive and negative aspects, ease, and difficulties present in the strategies for both the Preparatory Unit and the Summary Unit.

Lesson reports were written by all teachers and by both observers. This reporting was aimed at the evaluation of motivation, difficulties, ease, and adequacy of the strategies, as well as organization of the field trips.

A Portuguese version of the Science Outdoor Learning Environment Inventory (SOLEI; Orion et al., 1997) was applied at the end of the field trip to score the students' answers. The procedure to validate this inventory was done as described in next section.

Inventory

The authors' proposal was to adapt the SOLEI (Orion et al., 1997) and validate it for the Portuguese secondary school student population. The main objective was to adapt SOLEI so that it could be used for assessing the Portuguese geoscience student perceptions of field trips. Five of the SOLEI scales are based on the Science Laboratory Environment Instrument (SLEI), and the other two are specific to outdoor learning environments (Orion et al., 1997).

Adaptation and Validation

The potential of the SOLEI is stated by Orion et al. (1997). The authors refer to SOLEI as an instrument to be used with student samples from different cultural and educational sectors. The seven subscales of the original SOLEI version (organized under a 5-point Likert-type scale: 1 = never like to 5 = always like) was adapted to a Portuguese version in order to assess geoscience learning in the field.

After receiving permission to adapt the English version of the inventory, the adaptation and validation of the SOLEI went through the following steps: (1) adaptation to the Portuguese population, (2) preliminary application and analysis, (3) readapted application and reanalysis, and (4) final validation.

In the first stage, items were translated and checked by a bilingual educator with a good understanding of both English and Portuguese. An expert in geology education

TABLE II: Evaluation instruments used in different field trip stages.

Phase	Instruments	Respondent
Preparatory unit	Lesson report	Teachers/researchers
	Short questionnaire	Students
Field trip unit	Lesson report	Teachers/researchers
	SOLEI (Portuguese version)	Students
Summary unit	Lesson report	Teachers/researchers
	Short questionnaire	Students

TABLE III: Comparison between the original and Portuguese SOLEI versions.

Subscales	Adapted SOLEI Version		Original SOLEI[1]	
	Number of Items	Cronbach's Alpha	Number of Items	Cronbach's Alpha
A. Environment interaction	7	0.65	7	0.55
B. Integration of field trip and regular classes	10	0.71	9	0.76
C. Students' cohesiveness	9	0.69	6	0.66
D. Teacher support	10	0.77	7	0.71
E. Open-endedness	7	0.60	8	0.58
F. Student preparation for the field trip	10	0.70	7	0.73
G. Materials and environment	9	0.69	6	0.60

[1]Orion et al., 1997.

with a thorough knowledge in English then reviewed it and certain statements were revised. In the second stage, since some modifications and additions had to be made (both in the scales and items), the new inventory was adjusted. Three geology teachers and field study researchers adapted the item formulations in accordance with the techniques and specific terminology used in Portugal. Since ten items were considered misadjusted to the Portuguese context, the final preliminary version of the adapted SOLEI excluded these items. Some new items were introduced in each subscale, backed by the specific knowledge of geoscience educational field trips. The first final version of the Portuguese adaptation of the SOLEI included a total of 70 items. For the purpose of content validation, a group of three geology teachers and field study experts confirmed the validity of the inventory.

The experimental application of the initial instrument (with 70 items equally distributed across seven scales) took place in the Summary Unit of the field study, which was developed with a group of 21 secondary school students (average age, 15 years). The inventory purposely presented the items randomly and with no reference to the subscales or items that needed to be recoded. The purpose of this application was to verify the suitability of the adapted version of the Portuguese inventory. Students mentioned points with which they agreed, pointed out difficulties and made suggestions. This procedure resulted in the adjustment and rectification of vocabulary, as well as the structural improvement of each item. As such, the answers given by students were impartial.

During the fourth step of the inventory adaptation and validation, the 70-item Portuguese SOLEI version was applied to 280 geoscience students from two secondary Portuguese schools. As all participants had participated in a field trip organized in accordance with the Orion model (1993), with similar activities distributed within three stages, the sample used for the validation of the definitive inventory ($n = 280$) was considered adequate. Students took 30 minutes to answer the Portuguese SOLEI version.

The research then verified the consistency of the study by calculating the Cronbach's alpha internal consistency coefficient (Cronbach, 1951). This was accomplished by using the Statistical Package for Social Sciences (SPSS), version 18. Before statistical procedures were applied, the answers to some items were recoded. The definitive version of the Portuguese adaptation of the SOLEI was established with 62 items.

Table III presents subscales and its Cronbach's alpha consistency coefficient of the final version. Some values, although lower than 0.70 are also equal to or higher than 0.60. According to Loewenthal (2001), when (sub)scales hold few items, a Cronbach's alpha coefficient even as low as 0.60 can be statistically accepted for the purpose of social science studies.

After adaptation and validation of the inventory, some scoring classes were defined to assess the results of the participants (Table IV). Five classes were defined: I = low, II = middle-low, III = middle, IV = middle-high, and V = high, according to the values presented in Table IV. Student answers were allocated to each respective class, in each subscale.

TABLE IV: Scoring classes of the Portuguese SOLEI version.

Subscales	Number of Items	Classes				
		I	II	III	IV	V
		Low	Middle–Low	Middle	Middle–High	High
A. Environment interaction	**7**	7–13	14–18	19–24	25–29	30–35
B. Integration of field trip and regular classes	**10**	10–18	19–26	27–34	35–42	43–50
C. Student cohesiveness	**9**	9–16	17–23	24–31	32–38	39–45
D. Teacher support	**10**	10–18	19–26	27–34	35–42	43–50
E. Open-endness	**7**	7–13	14–18	19–24	25–29	30–35
F. Student preparation for the field trip	**10**	10–18	19–26	27–34	35–42	43–50
G. Materials and environment	**9**	9–16	17–23	24–31	32–38	39–45

FIGURE 1: (A) The banks of the Minho River with alluviums associated with fishing artifacts. (B) Outcrop showing the diversity of igneous and metamorphic lithologies and textures.

The scoring classes took into account the minimum and maximum values of each subscale and were calculated according to the respective number of items. The interval range for each subscale was distributed within the five classes, each establishing its own limits. For example: the scale has seven items; considering the minimum (1) and maximum scores (5), the interval of scale seven is set between 7 and 35. Accordingly, the limits determined for each class were as follows: I (7–13), II (14–18), III (19–24), IV (25–29), and V (30–35).

Procedure

Students from five classes participated in the field trips that took place on the left bank of the Minho River and included five study stations (Fig. 1A). The field trip, on the coastal area of Vila do Conde, comprised students from eight classes and had six study stations (Fig. 1B).

The left bank of the Minho River is mainly characterized by granitic lithology and some metasediments. Some sedimentary formations also exist, such as alluviums and fluvial terraces, while the river valley lies between faults and mountain ranges. Upriver, the slopes are abrupt and slope slightly downriver. The geological heritage includes rock outcrops, faults and other discontinuities, sedimentary deposits, and fishing artifacts that influence the river dynamics, sedimentation, meanders, and structures of erosion (Fig. 1A).

In the coastal area of Vila do Conde, the lithological diversity, which is associated with good outcrop conditions, make this a special and privileged area in which to do fieldwork in a school context. The igneous variscan rocks are the most representative lithologies in the region, with a predominance of syntectonic two-mica leucogranites, with different textural and mineralogical features. The alignment of granitic bodies is always in concordance with the structure of the surrounding metasedimentary rocks, often showing lenticular structures. Boundary zones are characterized by layers and patches of igneous lithologies in the surrounding metamorphic rocks. The textural and mineralogical variations of the igneous facies (Fig. 1B) and the features of the boundary zones are indicative of migmatitic lithologies.

Both geological areas presented similar aspects such as occurrence of structures of tectonic origin, magmatic and metamorphic relics, magmatic and metamorphic residues, and lithological diversity. Since these aspects are included in the Portuguese science curriculum, it was relatively easy to integrate these field studies into the science lesson plans in both of the participating schools. Instead of lectures or observation of rock samples in the classroom, teachers suggested to the school principal the development of a field trip in the area surrounding the school where these geological aspects could be seen and taught to students. As fieldwork is a strategy that can promote inquiry activities and the development of investigation competencies, field studies are integrated into the science curriculum, although they are generally neglected and replaced by lecture-based teaching, such as reading the textbook.

ANALYSIS OF THE RESULTS

The following analysis is presented according to the results of each evaluation instrument. The content of lesson report answers and short questionnaire answers was analyzed by two experts. Following the codification of the answers, if different codes were given to the same answer, other team member analyzed the process independently. This last procedure was done to guarantee the internal consistency of the codification process. Finally, data were organized into codes and then into broader categories, allowing the research team members to better analyze and to generate some conclusions.

Lesson Reports

Considering the teachers' perspective and by analyzing the written lesson reports, it can be concluded that fieldwork increases the student's learning motivation and interest, particularly in terms of the use of topographic and geological maps and a geologist's compass. Professor A wrote on his report that "*activities were diverse and in general were able to catch the attention and interest of the students*." Professor B stated that "*during fieldwork different tasks were done with spontaneity and a constructive participation of students was undertaken and a climate of enthusiasm was observed*." One of the participant observers wrote that "*field work activities increased the study of geology interest*." Professor C corroborated these ideas, writing that "*students had difficulties using*

TABLE V: Frequency distribution of the student answers for the score classes relating to the subscales of the adapted SOLEI (n = 280).[1]

Subscales	Classes				
	I	II	III	IV	V
	Low	Middle–Low	Middle	Middle–High	High
A. Environment interaction	0	10	60	**133**	**74**
B. Integration of field trip and regular classes	1	3	52	**119**	**92**
C. Student cohesiveness	2	2	**69**	**151**	49
D. Teacher support	1	1	40	**117**	**117**
E. Open-endedness	0	6	**112**	**116**	42
F. Student preparation for the field trip	1	3	43	**147**	**79**
G. Materials and environment	0	5	54	**130**	**83**

[1]Some students did not respond so the number of answers in a row may be less than 280.

the compass and in postfield activities they asked to analyze more topographic and geological maps.''

According to teachers, fieldwork also favored mutual help and collaborative work among participants. Professor D remarked that ''*students talk with each other about contents and tasks*.'' On the other hand, Professor E wrote that ''*students were receptive in performing the tasks,*'' and that ''*the collaborative work done to fulfill the field guide allowed the discussion among students*.'' Professor B stated that ''*a leader in the group was always required, improving the collaborative work and the motivation*.''

Fieldwork increased curiosity and eagerness to understand, and facilitated interpretation of the natural environment while enhancing the critical spirit and questioning capacity. In the lesson report of Professor F, it could be read that ''*fieldwork was seen as an awareness to realize the importance and the exploitation of natural resources*''; and that ''*students questioned and formulated explanations to what they observed*.'' This professor also stated that ''*critical spirit and a proactive attitude was stimulated, as well as attitudes to preserve the geological heritage and the sustainable development*.'' Professor A's written report concluded that ''*interesting questions were formulated regarding the field guide tasks, allowing problem solving and increasing students interest*.''

Furthermore, fieldwork allowed students to establish relationships between the conceptual contents previously taught in class and the geological aspects observed in the field. One of the participant observers wrote that ''*the work in the field consolidated content knowledge because it allowed students to visualize real field aspects, something that is not possible in the classroom*.'' The same participant observer also wrote that ''*opposite to textbooks that give examples from far way places, tasks in the field called attention to geologically relevant aspects of the surrounding area of the school*.'' Professor D's lesson report included the following sentence: ''*the integration of syllabus contents with practical activities is well done in the field*.'' Finally**,** Professor B stated that ''*in the field, students acquired more knowledge regarding the geology of the region, being able to better understand some conceptual content taught in the classroom.*''

Short Questionnaire

Analysis of the student questionnaires demonstrates that students valued fieldwork because it promoted better understanding of the geology around their school and permitted direct observation of the rocks and geological structures in the local natural environment. Some students' answers that support this conclusion are: ''*the direct contact with situations, supported by some theoretical explanations with the miniposters, stimulated us to environmental protection and a healthy life in the outside*''; ''*I would like to know more about out-of-school settings and learn more about the geology of the school area*''; and ''*I have learned very interesting geology aspects of this region*.''

Moreover, it facilitated the use of the compass-clinometer and both geological and topographic maps, enhanced collaborative work, and improved the relationship among the students and between students and teachers. Students that conducted the field study in the Minho River wrote: ''*my biggest task facility was in using maps during group work*''; ''*teacher was very patient improving our self-esteem*''; and ''*I learned to use compass, to classify rocks, to read maps, and to observe and explain geology aspects*''.

Fieldwork enhanced observation competencies and developed student autonomy, and improved understanding capabilities, reasoning ability, and the relationship between conceptual knowledge. Students wrote that they ''*learn to like geology*'' and that ''*with the fieldwork, finally some theoretical aspects were understood, even those not very well clarified in the classroom*.'' The fieldwork also referred to the outdoor classroom where ''*many issues were better conceptualized*'' ''*with many, but easy tasks,*'' which were done ''*with pleasure and motivation*.''

Finally, fieldwork improved the ability to perform several scientific procedures, such as observation, interpretation, measurement, and recording. Students referred to ''*the easy observations in the field, namely in rock classification*'' to how they ''*learned to use the compass and how to analyze some observations*.''

Results of the Inventory Application

The results of the student answer scoring process in relation to the adapted Portuguese SOLEI version, are shown in Table V (absolute frequencies) and Fig. 2 (percentages).

By observing the scoring of the 280 participants (Table V), it is obvious that students scored mainly in the *middle* and *middle-high* categories for subscales (C) *Student cohesiveness* and (E) *Open-endedness*, while the remainder scored were mainly in the *middle-high* and *high* categories. Class IV

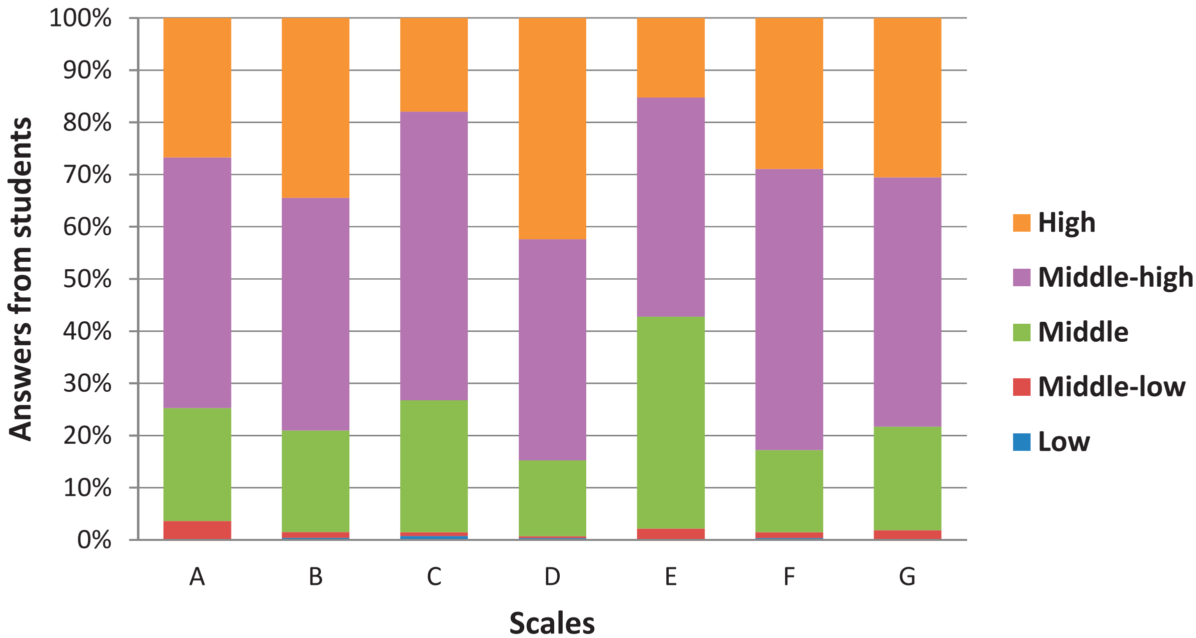

FIGURE 2: Results obtained from scoring the answers in the seven subscale classes.

presented a higher frequency in almost all scales: A (*Environment interaction*) 48.0%, B (*Integration of field trip and regular classes*) 44.6%, C (*Students' cohesiveness*) 55.3%, E (*Open-endedness*) 42.0%, F (*Student preparation for the field trip*) 53.8%, and G (*Materials and environment*) 47.8%. In general, the results were very positive and the suitability of the field trip planning was demonstrated. Students who participated in the active outdoor learning events presented significantly more positive perceptions in each of the seven scales.

CONCLUSIONS AND EDUCATIONAL APPLICATIONS

Evaluation of the field trip efficiency was carried out according to the Orion organizational model. As a strategy for geology teaching, evaluation underlined the advantages of including fieldwork in the secondary Portuguese science curriculum. The results of this study clearly demonstrate that fieldwork and field studies provide an effective means of communicating knowledge to students, as well as a motivational strategy to help them learn about geology and environmental issues. Students were able to clarify content knowledge learned in the classroom by establishing comparisons with related phenomena observed in the field, which demonstrates the development of students' conceptual knowledge and understanding, as well as some science procedures. Moreover, an improvement in the students' awareness of the need to preserve geodiversity was noted, especially that of the region surrounding the school. The results also showed that the field studies organized according to the Orion model (1993) can be a successful instructional strategy and can create a positive learning environment, as discussed in studies conducted in other countries. As such, the study recognizes the need for curriculum designers to consider the inclusion of this strategy in the Portuguese curriculum.

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