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Field activities, science education and problem-solving

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Abstract

Portuguese science curricula acknowledge field activities as important tools for students to learn science and to relate science knowledge with the outside school world. The educational outcomes of this type of activities depend on the way they are organized and integrated into the teaching sequence. This paper presents a typology of field activities named after their main educational goal and categorized with regards to a set of educational criteria. Afterwards, it discusses the extent to which each type of field activity is consistent with problem-solving, namely with a problem-based learning approach.

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1. From field work to field activities

Portuguese science curricula guidelines (DEB, 2001) acknowledge field trips as important tools for students to learn science and to relate science knowledge with the outside school world. This paper assumes that field trips, field work and field activities are related but different concepts. As a matter of fact, a review of the specialized literature reveals that over the years, several different words have been used to address the same or related entities associated with teaching outside the classroom and that they are not clearly defined and differentiated. Words like field work (Dummer, Cook, Parker, Barrett & Hull, 2008; Lock, 1998; Marques, Praia & Kempa, 2003; Schnoebelen, 1990), field activities (Dourado, 2001; Viveiro & Diniz, 2009), educational field activities (Diez, Martín & Vicente, 2008), field trips (Brusi, Zamorano, Casellas & Bach, 2011; Mckenzie, Utgard & Lisowski, 1986; Orion, 1993; Scortegagna & Negrão, 2005), excursions (Compiani & Carneiro, 1993; García, 1994), and study visits (Andrade, 1991; Oliveira, 2008; Varela, 2009) are among the words commonly used to address such entities. This paper acknowledges Lock's definition of field work as the whole set of the all possible types of field activities, with diverse aims, structures, content, etc. Thus, it is conceptualized as a single entity

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that has encompasses all activities that students do outside the classroom, whatever they do it in open space or outdoors, to learn and develop relevant competences. However, its singular form does not enable to differentiate among field activities.

Based on Millar, Tiberghien & Le Maréchal's (2002) proposal for differentiating lab activities from lab work, this paper acknowledges that field activities differ from field work as the former have to do with a diversity of tasks that are carried outside the classroom; where the events to be studied take place; where the natural phenomena happen and can be observed as they happen, without the need of being reproduced; or in real work contexts, where technology is used for industry and production purposes. As a matter of fact, the word field in field activities suggests that there are activities that can be done outside the classroom and the plural form of activities indicates that there may be activities that are quite different from each other.

Field activities may start and/or continue in the classroom or in the school lab but they take place outside them. Therefore, in order to do field work and field activities, there is a need to do a field trip which includes going out of school and taking a journey to the place where the activities are to be performed. Preference for the word field trip instead of field visit has to do with the fact that field visit seems more leisure like and time limited than field trips are. Similarly, the word excursion activates meanings and ideas related to leisure. Although there is nothing wrong with associating learning and pleasure, it does not seem appropriate to emphasize leisure over learning. Finally, the word study in the designation study visits emphasizes the learning part but it goes together with a more time limited and leisure related word (visit) that may withdraw some seriousness from the former. However, it should be noticed that doing field work does not necessarily require a long trip (Del Carmen, 1999). In short, when one takes a field trip to do field work, one can do one, two or more activities, with quite similar or very different objectives and structures. It should also be noticed that field activities are different from a class outside the classroom, for example, in a museum or a university. In fact, in these cases, and opposite to what happens when field work is at stake, the place where the class will happen is different from the usual one but there will be no students' contact with the truly real world. If one wants students to be involved into field activities, a field trip has to be planned and organized and it can include the performance of one or more field activities which are relevant for one or more school subjects.

The objectives of this paper are: to present a reconceptualizing synthesis of the variety of field activities that can be thought of; and to discuss their relative consistency with a problem-solving perspective. The relevance of the paper lies in the fact that there are quite a lot of texts dealing with the first issue but they are written in diverse languages, do it in parts and use quite different words to name the same entities. This diversity makes it hard for the reader to make sense of all that stuff. Besides, there is no global discussion on the relationship of field activities and problem-solving in science education. This lack of discussion may impair teachers from becoming aware of the relative strengths and limitations of the different types of field activities and consequently it may prevent students from being involved in truly problem-solving and problem-based learning of science situations.

2. Curriculum scope of field trips

Taking students out of school requires deciding on the scope of the field trip and setting up a set of administrative procedures as well as obtaining parents' authorizations for their children to take the trip.

As far as the scope of the field trip is concerned, it has to do with the way the field trip is integrated into the curriculum as well as with its intended educational objectives. A field trip can be organized within a single school subject or it may be planned by a few school subjects together. In the former case, the field trip is discipline-based and it focuses on places or issues that are relevant for the school subject within which the field trip is organized. In the latter case, field trips can be integrated within the diverse school subjects and this can be done in several ways, some of which may have higher disciplinary integration degrees than others do, depending on whether the field trips are multidisciplinary, pluridisciplinary, interdisciplinary or transdisciplinary in nature. Bearing in mind Costa's (2012) and Dalrymple & Miller (2006) definitions of these concepts, these types of field

trips can be distinguished from each other based on the way they deal with places or issues analyzed during the field trip, as follows:

- multidisciplinary field trips: each school subject that is involved in the field trip concentrates on a place or issue, looks at it from its own perspective and makes it explicit some relationships between that place or issue and the content of the other subject(s);
- pluridisciplinary field trips: the diverse school subjects focus on the same place or issue, look at it from their own perspectives but they previously agree among them how they approach the object in order to avoid undesirable or even confusing repetitions and to save time;
- interdisciplinary field trips: all the school subjects involved in the field trip concentrate on the same place or issue, they approach it from each one's perspective although in such a way as to complete each other's point of view and to foster knowledge integration;
- Transdisciplinary field trips: all the school subjects concentrate on the same place or issue which is approached in a holistic way, so that the barriers between school subjects are vanished.

A field trip is often imagined as something that requires a long journey. However, this has not to be (Del Carmen, 1999) and is not (Howarth & Selingsby, 2006; Lock, 2010) necessarily the case, as very productive field trips can require short journeys. The local public garden, the village river, the public park pond, or the school garden or the playground wall can be relevant field trip destinies, as they can provide material to be explored in biology, geology or even physics and chemistry school subjects. Besides, the most frequent field trips concentrate on the surface of the Planet, but they can also have the underground (e.g., caverns) or on the sea (e.g., deep water sea) as their destiny.

As far as learning outcomes are concerned, a field trip can both help students to develop several different competences (Brusi, Zamorano, Casellas & Bach, 2011) and have a variety of learning goals (Braund & Reiss, 2004; Compiani & Carneiro, 1993; Lock, 1998). The latter include to serve as a way of complementing school-based activities (e.g., visit to a chemistry industry laboratory, after studying the ammoniac synthesis at school), to allow the contact with the natural world (e.g., to visit some natural caverns, in order to see stalactites and stalagmites) or with some natural (e.g., to visit a set of sand dunes, in order to understand how they are formed) or social (e.g., visit a fishermen to understand his ways of leaving) phenomena. Whatever the case, according to some authors (Braund & Reiss, 2004; King & Glackin, 2010; Lock, 1998) a field trip may be organized in such a way as to enable students to attain objectives related to:

- conceptual learning, that is objectives that focus on strengthening previously acquired conceptual knowledge, constructing 'new' conceptual knowledge, or reconstructing students' conceptual knowledge (which is especially interesting when students hold alternative conceptions on the concepts to be studied within the scope of the field trip);
- procedural learning, that is knowledge of specific purposes observation techniques (e.g., birds needing), samples collection (e.g., water from a river), conservation and transportation of materials (e.g., plants or animals) that need to be mastered by students;
- epistemological learning, that is knowledge relative to the characteristics of the scientific methodology relevant in field contexts, as well as to the (un)certainly of the science explanation and to the nature and role of models in (physics, chemistry, biology and geology) knowledge development;
- attitudes development, namely those related to respect towards the environment and towards science as well as scientific attitudes;
- interpersonal relationships, which have to do with respect to others, and cooperation with colleagues;
- contact with nature and real contexts, aiming at making students' aware of the complexity of the real world and the interactions that it comprises;

- questioning abilities, that is asking questions about nature and work contexts to understand, improve and take profit from them;
- extrinsic motivation, that has to do with fostering students' interest and curiosity towards real world work contexts.

As far as it is appropriately planned and organized, several of these objectives can be attained together within the scope of a single field trip. Success on attaining this goal depends on the activities planned to be carried out during the field trip and the way they are structured and implemented.

3. Types of field activities

As referred to above, field activities can help students to both attain diverse broad learning objectives and develop several competences. To succeed on doing so, they must have a structure appropriate to fitting those objectives. To differentiate among activities with diverse objectives and structure, Compiani & Carneiro (1993) use the following set of criteria:

- main learning objective to be attained through the activity;
- main teaching purpose, that can be formative (stressing the process of learning) or informative (stressing knowledge transmission or development);
- use or questioning of conceptual knowledge, as they can focus either on the use and preservation of students' conceptions and models on cognitive conflict and students' knowledge reconstruction;
- teacher's and students' roles, that can be student centered, teacher centered, student and teacher centered or guide centered teaching;
- dominant teaching logic that is, the logic that informs teaching process (that is, science or student logic).

When commenting on Compiani & Carneiro's criteria, Pedrinaci, Sequeira & García (1994) argue for the relevance of the teaching perspective for differentiating between field activities. According to these authors, the teaching perspective determines what is done and learned from a field activity. Taking together, these two sets of proposals seem to be useful although not enough to clearly distinguish among the diverse types of activities, as they do not make it explicit criteria like integration of the field activity in the teaching sequence. Hence, it seems that the different types of field activities can be differentiated from each other based on the following criteria:

- main learning focus: motivation, practical skills, and procedural, conceptual or epistemological knowledge
- underlying teaching and learning perspectives: transmission, guided discovery, discovery, constructivist, social-constructivist
- integration in the teaching sequence: before, during or at the end
- teacher's role: watch students, demonstrate, question students
- students' role: observe, perform, watch, solve-problems
- science skills and attitudes development: ignored, used, developed
- access to relevant conceptual knowledge: doesn't apply, given to students, 'discovered', constructed by the student
- role of student's previous knowledge: preserved, used, questioned
- availability of scaffold elements: no scaffold available, teacher and/or worksheet available
- acknowledged prevailing logic: science logic, student's logic
- interpersonal fostered relationships: none, student-student, student-teacher
- communication skills developed: questioning, answer, argument
- interaction with the environment: -intrusive, -non-intrusive

Table 1 shows a characterization of the types of field activities that may result from the use of these criteria and that are named after their outstanding educational objectives. In this context, outstanding objective means an objective that can be better attained through a certain type of field activity rather than through the others.

Table 1. Characterization of the diverse types of field activities

Classification Criteria	Types of field activities						
	Motivating	Training	Illustrative	Guided observation	Inductive	Problem posing	Problem-solving
Main learning focus	Motivation	Practical skills	Conceptual	Conceptual	Procedural and conceptual	Procedural and epistemological	Procedural, conceptual, and epistemological
Underlying teaching and learning perspectives	Transmission	Transmission	Transmission	Guided discovery	Discovery	Constructivist	Social constructivist
Integration in the teaching sequence	Before	During or after	End	During	During	Before	Before, during, after
Teacher's role	Watch students	Demonstrate	Demonstrate or watch students	Watch students	Watch students	Watch students	Watch and question students
Students' role	Observe	Perform	Watch or perform	Observe	Observe and Perform	Observe	Solve problems
Development of science skills and attitudes	Ignored	Developed	Used	Used	Used and developed	Developed	Developed
Access to relevant conceptual knowledge	Doesn't apply	Doesn't apply	Given	Given	"Discovered"	Doesn't apply	Constructed
Role of student's previous knowledge	Preserved	Preserved	Preserved	Used and Preserved	Used and preserved	Used and (later) questioned	Accepted and questioned
Availability of scaffold elements	Unavailable	Teacher	Teacher	Worksheet	Teacher	Unavailable	Unavailable
Acknowledged prevailing logic	Student	Science	Science	Science	Science and student	Science and student	Science and student
Interpersonal fostered relationships	None	None	Student-teacher	Student-student	Student-student	None	Student-student
Communication skills developed	None	None	Answer	Answer	Argument	Questioning	Questioning, argument, answer
Interaction with the environment	Non-intrusive	Intrusive	Intrusive or non-intrusive	Non-intrusive	Intrusive or non-intrusive	Non-intrusive	Intrusive or non-intrusive

Despite the fact that an outstanding objective was associated to each type of activity it should be stressed that each activity may lead students to attain some objectives that are common to other types of activities. To illustrate this it can be expected, for example, that all types of field activities motivate students (Lock, 1998) and should promote their respect towards the environment. However, some field activities can be planned and performed just to raise students' extrinsic motivation towards science learning even though this type of activity makes more sense within a transmission, teacher centred, approach than within a student centred, constructivist, approach as the latter is more prone to generate intrinsic motivation than the former. On the other hand, although

developing respect towards the environment should be an ever present issue, explicit action must be taken so that students develop respectful and protecting attitudes towards it when they do field activities.

In the whole, field activities have a diversity of main distinguishing objectives, ranging from the motivational ones to the problem solving ones, passing by the conceptual and the procedural ones. Table 2 shows the main distinguishing objective of each type of activity characterized above, as well as a brief description of an example of each type of the activity.

Table 2. Outstanding objectives and examples of the diverse types of field activities

Types of field activities	Outstanding objectives	Examples
Motivating	To raise students' interest for an issue to be studied later on	Observe a river where dead fishes were found (before studying pollution causes and effects)
Training	To promote the learning of technics and the development of skills with diverse degrees of complexity	To learn how to use the compass in order to measure the slope and the direction of a geologic plan.
Illustrative	To strength previously acquired knowledge	Observe and analyse the types of rocks of the school surrounding to ascertain that they are those that were mentioned in the classroom.
Guided observation	To 'discover' or to ascertain something based on a worksheet.	To observe the process of industry ammoniac production based on a worksheet that makes it explicit the phases of that process.
Inductive	To observe and interpret in order to discover conceptual knowledge	To compare the types of plants that grow on sun exposed and non-exposed areas (to conclude that they depend on the exposure to sun light)
Problem posing	To develop an investigative spirit	To observe a place (e.g., an abandoned mine exploration) and to identify the issues that deserve being studied or worked out (to learn about or to solve some of them later on)
Problem-solving	To solve a problem	To find out the reason why the water from the Seven Oaks water source is turve.

4. Field activities and problem-based learning of science

As it was referred to above, many people do not distinguish field work from field activities, and consequently they can hardly differentiate between potentially different learning opportunities that may arise from the diverse ways that field activities can be structured and integrated in the teaching and learning sequence. The effect of this is that they do not look critically enough to the activities that they include in a field trip, namely with regard to their probable effective learning outcomes. Besides, many people believe that having students doing whatever kind of field activity is good and means giving them the opportunity to do an investigation. This is not so as doing field work is not necessarily better than not doing it; its educational value depends on whether or not it makes a meaningful difference in terms of learning outcomes. In addition, and as it was argued above, doing activities in the field may mean carrying an investigation, consistent with a social constructivist perspective, or it may rather mean confirming what the teacher said, within a transmission and reception behaviorist educational framework.

Although it may make sense to do several different types of field activities (Scortegagna & Negrão, 2005), not distinguishing between them may nevertheless impair students from taking the chance of doing investigations. These are the most complex activities for students to do but they may lead to broader and deeper learning (Jaén & Bernal, 1993; Orion, 1993). On the other hand, they may also make the teacher feel more uncomfortable because he/she can no longer keep on 'telling knowledge' to students. In fact, if investigations are conceptualized as problem-solving activities, then an analysis of the characteristics of field activities described in table 1, indicates that most of them do not fit that criterion. In fact, when solving a problem is at stake, the problem solver has to

draw a strategy to overcome an obstacle that the problem statement faces him/her with. The obstacle may have to do with a real difficulty that has to be overcome or an immediate personal or social need that has to be fulfilled, but it may also have to do with an issue that requires deep understanding. Hence, motivating and training field activities are not consistent with the idea or problem-solving activities, as they are not organized around a problem. Illustrative activities are not consistent with problem-solving either, not only because their answers (solutions) are known beforehand but also because the strategy that should be followed to attain that aim is given and, consequently, there is no need to design a strategy to overcome an obstacle, as required by problem-solving.

Directed observation activities differs from Illustrative activities because in the former case the solution is not known in advance (opposite to what happens in illustrative activities) but the worksheet offers students the strategy to be used to get the *right* solution that is, the only possible solution. Inductive activities are more open but they still ask students to follow some general guidelines, deriving from some basic principles of scientific methodology, like observing, collecting data, draw conclusions and make a generalization. These guidelines lead students to a solution that hopefully is to be generalized. On the contrary, problem posing activities lead to problem statements rather than to problem solutions. Therefore, they fit the first student-centered phase of a PBL approach (Lambros, 2004), as they could work as a way of finding the problems to be later solved by the students, either in the field, in the lab, in the classroom, or wherever the relevant tools and resources are available. Finally, problem-solving activities require students to solve a problem to develop procedural, conceptual and epistemological knowledge. Depending on the phase of the teaching process that they are used, problems can work as starting points for learning or as tools for deeper understanding, or even as evaluation tools. If the former is the case, then problem-solving field activities are used as starting points for new learning, so that students will learn new knowledge (from their point of view) by working on a problem in order to get one or more solutions for it. In the other cases, the problem would come after new knowledge being learned and therefore, problem solving (but not problem based-learning) can take place.

Thus, both problem posing and problem-solving activities (if the latter are used at the beginning of the teaching and learning sequence) can fit a problem-based learning approach. Besides, problem posing field activities can precede the problem-solving ones, as the former can provide problems to be solved through the later, and therefore serve as scenarios for problem-based learning.

5. Using field activities for science problem-based learning

Problem-based learning (PBL) has to do with learning new knowledge by solving problems (Lambros, 2004), that is by getting answers to questions. Those answers may be conceptual or procedural answers or they may be practical ways of overcoming an everyday issue. Besides, each problem may have an answer, two or more possible answers or no answer at all. In addition, problems to be solved can be given to students or students can be asked to pose them from some sort of scenario. In the latter is the case, the scenario needs to be appealing for the target students, so that they pose problems that they feel are worth being solved. In fact, afterwards, students are supposed to work on problems that they should feel worthwhile working on, in order to solve them, preferably, in small groups working cooperatively.

Thus, if PBL involving field activities is to be carried out, then two things may happen: either problems are given to students so that they can solve them through problem-solving field activities; or problems have to be posed by students, for example within the context of a problem posing field activity, and afterwards they can be solved within the context of a problem-solving field activity. In the latter case, at least two types of field activities would be carried out one after the other. However, it should be noticed that whatever the way problems 'appear', they are supposed to be solved before theory is taught, as they are tools for learning rather than tools for showing that theory is correct (Marion, 1999) or for evaluating students' learning.

When using field activities for science problem-solving is at stake, a field trip has to be organized. Due to the diversity of tasks that have to be carried out so that the aims of the field trip are accomplished, it is convenient to

consider three phases: before the trip, during the trip and after the trip. Before the field trip, the place has to be selected, permissions for doing and attending the trip have to be obtained, the problem has to be understood by the students, and the activities to be carried out during the field trip have to be planned and prepared. It should be noticed that if problems come from a problem posing field activity, then this phase may require students to go out in order to perform a problem posing activity. This would enable students to pose problems to be taken back to school and worked out (analyzed, reinterpreted, etc) and then solved within the second part of the field trip. During the field trip, students are asked to carry out the activities previously planned, together with others that they may meanwhile feel as relevant to solving the problem(s) that are at stake. That may include *in loco* data collection and analysis as well as collection of sample materials to be taken to school to be studied, for example, in the lab. Collecting samples may be a requirement of the problem and a necessary condition for an appropriated study of the issue it involves. It requires the mastery of the appropriate technical procedures (that may be learned through a training field activity) so that the samples are not damaged. However, it should be taken as (an additional) opportunity for making students aware of the need to preserve the environment. Limiting the amounts of material collected may be a way of doing it. Afterwards, when back at school, students need to complete the activities done in the field and/or to do a balance of what was planned and accomplished. In addition, the solution(s) to the problem(s) have to be evaluated for their scientific, technological, environmental and/or social quality as well as for their fairness. Conclusions drawn by each small group from the activities carried out should be shared with and discussed by the class, so that not only students learn from their counterparts but also teacher can get some feedback about his/her students learning achievements. It may happen that work done in this phase reveals that a new trip is needed so that the issue can be completely understood and the problem can be solved. Thus, learning by problem solving field activities, may require a single trip, to solve the problem given to students, or it may involve two or three trips so that students can pose problems to be solved, collect the information (initially) required, and/or collect complementary information to solve the problem(s).

6. Final remarks

Several authors have emphasized the educational value of field activities (King & Glackin, 2010; Marion, 1999; Rebelo, Marques & Costa, 2011) but they are rarely used by teachers (Dourado, 2001; Rebelo, Marques & Costa, 2011) and when they are, the way they are structured and implemented is often inappropriate for taking most profit from them. A reason for that may lie in the fact that field trips are not distinguished from field work and from field activities and the educational diversity of field activities is not perceived either. Different types of field activities have different learning outcomes. Problem-solving activities are those that may foster the integrated development of a larger diversity of competences (Lambros, 2004) but they require competences that may be better developed within the scope of other types of field activities. In addition, they are those that give students the most active cognitive role as learners and therefore better prepare them for lifelong learning. Nevertheless, action must be taken to prevent that students learn more about the place visited than about the concepts that motivated the trip (Balci, 2010).

The argument that all types of field activities have a role to play in science education can be extended to other school subjects being Geography one of them. In fact, physical geography is similar to science, namely to geology and environmental science, as all of them share issues associated to large time scale and large dimension phenomena. They also share several curriculum themes and therefore can approach together several common problems, in an integrated way. Doing it this in this way will enable science and geography teachers to better prepare students to continue learning in the future as a citizen living in an ever changing society.

However, bearing in mind junior high school students' reactions to problem-based learning in the classroom (Leite, Dourado, Morgado, Meireles, Azevedo, Alves et al, 2013), it can be expected that students usually classified as 'good students' may show negative reactions and anxiety towards problem solving field activities and that the weaker students may show a great enthusiasm towards them. Hence a balance has to be achieved so

that all students keep appropriate levels of motivation and anxiety and can achieve the settled learning outcomes. Besides, teachers need to learn how to cope with their new role, of student supporters that they cannot ‘tell knowledge’ to them but that have to create conditions for students to actively learn new knowledge by solving problems outside the classroom. Besides, teachers need to select and promote the use of assessment techniques that fit the diversity of learning outcomes that is expected from the field activities carried out. As Dummer, Cook, Parker, Barrett & Hull (2008) have concluded, when field work is done, “clear assessment guidelines and assessment criteria are essential and many students do not appreciate flexibility in approach over and above detailed guidance” (p.473). Students need to know what is expected from them and teacher needs to have it clear so that he/she can provide appropriate support and promote the assessment of relevant learning issues done by the best informants, either student, peers or teachers.

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