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Teaching and Learning in Geosciences for Citizenship: From the Margins of Knowledge to the Central Tasks of Forming Teachers

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Abstract

The way of teaching Geoscience seems frozen in time, because it has been the same for some decades; classes dialogued, today, constitute, for many people, "the most advanced approach" in education. This paper, part of the doctoral thesis of José R. S. Martins (in progress), presents the following assumptions: (1) most students who attend formal education in Brazilian schools are at the margins of knowledge; (2) the best way (methodology) to form ethical and responsible citizens should be a conflict whose goal is to widely disseminate scientific education, leading to the largest possible number of students. Moreover, it is based on the need of education to be in conjunction with the social demands of learners, turning their achievements into agency. For future citizens to have their demands met, it is necessary that the essentialism and metanarratives of science are problematized and, thus, finding a response to the needs of learners to the construction of new concepts and paradigms. Initially, we justify the choice for the theme by showing its importance, some hypotheses and assumptions. Then, starting from the historical analysis of scientific methods, we show how important it is to provide quality science education to everyone. In the second part, the paper attempts to illustrate that the Method of Rediscovery, as well as the Science, Technology, Society and Environment (STSE) approach are not enough for scientific training of students nowadays. In response to these challenges, this paper proposes the establishment of active methodologies, which can lead to a process of graduating a critical mass of teachers and researchers engaged in training citizens. To this end, the process of teaching and learning must be built on the students´ social demands, and, regardless of grade and level chosen to apply the methodologies, the importance of teaching Earth Science in basic education can be easily demonstrated.

Keywords: Education, Geosciences, Transdisciplinar Studies.

Introduction

Along many decades the essence of Geoscience teaching has been the same. Therefore, it seems to be currently "frozen in time": in terms of education, many people consider classes dialogued as the most advanced approach.

This paper, part of the doctoral thesis of Martins (in progress), presents the following assumptions: (1) most students who attend formal education in Brazilian schools are at the margins of knowledge; (2) the best way (here considered as a methodological way) to form ethical and responsible citizens should constitute a clash whose goal is to disseminate scientific education widely, thus trying to influence the largest possible number of students. Moreover, this may attend the need of education to be connected to the social demands of learners, thus valuating their achievements and giving to the achievements an outstanding position.

The thesis aims to show that education of the people meets important social functions, as fundamental as vocational training of students on Geosciences, because it contributes to the formation of citizens and to develop their abilities and capabilities.

Four steps constitute the first half of the paper: initially, (1) we justify the choice for the theme by means of recognizing the importance, the hypotheses and assumptions of Science Education and 'Education for Life'. Then, starting from (2) a historical analysis of scientific methods, and (3) a few questions about teacher training, we show (4) how important it is to provide quality science education to everyone. The second half attempts to illustrate that the Method of Rediscovery, as well as the approach yielded by Science, Technology, Society and Environment (STSE) are not sufficient for scientific training of students nowadays.

In response to these challenges, some active methodologies may be proposed, which can lead to a process of graduating a critical mass of teachers and researchers engaged in training citizens. To this end, the process of teaching and learning must be built on the students´ social demands, and, regardless of grade and level chosen to apply the methodologies, the importance of teaching Earth Science in basic education can be easily demonstrated.

Science Education

For future citizens to have their demands met, it is necessary that essentialism and metanarratives of science be problematized; this may help to find a response to the needs of learners towards their construction of new concepts and paradigms.

As important as the discussion of science in the twentieth century is the comprehension of science by itself. Science, supported by methodologies and paradigms that frequently show 'more of the same', is usually regarded as

neutral, taken as the most perfect version of the concept of truth. The idea of neutrality, one of the great metanarratives of science during the last century, is refuted from discussions about the ambiguous use of nuclear energy; the idea of essentialism, as discussed by the philosophical instance of totalility (of an interdisciplinary nature) and the methodological discussion of transdisciplinar complexity, become questioned in terms of the acquisition and use of knowledge, whether scientific or everyday knowledge (Bizzo 1999). Santos (1993) recognizes a double epistemological rupture, catalyzed by social sciences, that defines a crisis in the current paradigm of science, which will culminate in the transformation of scientific knowledge into new everyday knowledge (or new common sense).

As the study of Geology enables reflections on the rational use of technological advances and applications of science, it can be demonstrated that Earth Sciences have an important humanistic side, because it may inculcate solidarity and humanitarian attitudes among younger generations (Carneiro et al. 2004).

Geoscience Education and Education for Life

Geology provides an overview of the functioning of the Earth system, what is necessary to understand the complex dynamics of the planet, more and more affected by humans that are currently an important geological agent (Loon 2001). Geologists and Earth Science educators have the great responsibility of transforming Geoscience education onto "*a process that must go beyond mere teaching and learning the facts, laws and theories; it must involve understanding the nature of Geoscience and its relationships with society*" (Bezzi 1999, p.696). Such a broad statement, whilst giving a suitably accurate compass to Geoscience teaching, fails to provide details. However, a synthesis by Orion & Ault (2007, p.655, apud King, 2008) highlights the following attributes of Geoscience study:

- the historical approach;
- the concern for complex systems acting over the Earth;
- the conceptualisation of very large-scale phenomena through time and across space;
- the need for visual representation as well as high demand upon spatial reasoning;
- the integration across scales of solutions to problems; and
- the uniqueness of retrospective scientific thinking.

The objectives of geological studies and their research methods valuate a high-level ability linked to temporal and spatial thinking, which is part of key attributes that King (2008) recognizes as not commonly found "in other areas of the science curriculum or within the curriculum in general". The study of Geosciences and the effective practice related

to education in Geosciences require thinking and research skills that are somewhat unusual, because "they are not well developed elsewhere"; they play a fundamental role in science education and 'Education for Life':

- Earth science is '… an interpretive and historical science' (Frodeman, 1995, p. 960) involving a wide range of methodologies including those required for retrodictive thinking ('prediction' of the past), for large-scale thinking and for integrating large and incomplete data sets.
- Geosciences plays a crucial role in the development of holistic systems thinking, involving consideration of major Earth systems, such as the water and carbon cycles and their interactions and positive and negative feedback loops.
- Geosciences requires high-level spatial ability thinking (three dimensional thinking).
- In Geoscience, the development of time perspectives is crucial, particularly those of geological time.
- Geoscience fieldwork has particular strategies and methodologies that must be acquired (which range from particular observational and recording skills to the high level analysis and synthesis skills necessary for understanding the multi-faceted field context). These strategies and methodologies involve development of all the attributes listed above, in field contexts. (King, 2008, p.188-189).

The five attributes listed above provide a structure for the research review. An overview of the teaching of Geosciences worldwide provides a scenario for the discussion.

Teacher Training

There is no consensus among researchers about paradigms, models and basic guidelines for initial teacher training (Pezzato, 2011). Teachers should basically transmit knowledge to students and stimulate them to ask questions and to look for answers by themselves. In spite of the fact that the curriculum of Science disciplines in the Brazilian basic education is "too fragmentary and superficial" (Carneiro et al., 2004), these procedures may help promoting an interpretation of the world and contribute to form values and citizenship (Pezzato, 2012).

Training is essentially an action towards giving a teacher a chance to build his/her competence: the ability to transform knowledge, skills, and attitudes in results. The profession of teaching faces increasingly complex demands, a cause for more pressure over the required skills and competence of teachers.

Teachers are expected to get meaningful learning, but at the same time they should also inspire their students to do the same.

Meaningful Learning

Meaningful learning in a Science discipline is what offers the learner the condition of to think freely and apply his/her knowledge in order to solve new problems. For a graduate geologist, it is an opportunity to investigate real situations that he/she has to face.

Geoscience Education gives great importance to the investigative method, which consists in observing, collecting and processing information to raise and test hypotheses, draw conclusions and present the results (Brazil, PCNs 1998a, p.115). This approach enables one to develop skills supported in collaboration, brainstorming and treatment of various types of information, as well as ability to perform oral, visual and written presentation of research results.

The establishment of specific content areas of science and geography by the Department of Elementary Education involved the proposition of the National Curriculum Parameters, known as PCNs. In the late 1990s, it launched the NCP Cross-cutting Themes (Brazil 1997, 1998b), which aims to promote citizenship education supported in the social reality of the student. In other words, these regulations allow taking into account the context in which knowledge is generated, assimilated and reproduced. This may help many Brazilian students in formal education to escape from their present-day marginal position in regard to the scientific knowledge.

Carneiro et al. (2004) present a list of ten reasons to which they have added two, in which the insertion of Geosciences can improve the quality of Brazilian education and culture in general. While some are specific to science education, Carneiro and Signoretti (2008) point out developments in the teaching of Geography and Geosciences. Martins (2010) and Martins and Carneiro (2012) have presented a further discussion on these 12 topics.

The Method of Rediscovery

The Method of Rediscovery and the STSE approach (Science, Technology, Society, and Environment) have contributed during the 1960s, and the following two decades, for teaching/building concepts in Geosciences.

The Method of Rediscovery is of great importance in fundamental teaching (K-6 up to K-14), a time when many students have not developed their capacity for abstraction, that is required to build certain ideas. The method intends to bring students to construct scientific concepts from problem situations formulated using sensorial experiments. To this end, it is adopted a pre-established route in accordance with a straight scheme of study, which leads students to answer questions formulated at the beginning of the activity. The procedure is planned towards making students: to “act as a scientist”, to

exploit their previous notions, to establish new ways of thinking about the initial question and ultimately to restructure these notions in the form of a new concept.

The STSE approach (interdisciplinary in origin) is mainly applied to students of secondary and higher education; it proposes to work on science concepts from knowledge acquired in the various school subjects through integration projects, cross-cutting themes and development of skills and abilities. Unlike the method of Rediscovery, the STSE approach has its canonical science contents associated and integrated with the everyday world of students, mirroring the natural efforts of learners to make sense of the world (Aikenhead, 2009, p.22). In this approach, science is brought into the world of a student by an alleged need to understand that this is the world, being opposite to the method of Rediscovery, which defines that the student should enter the world of science and, then, adopt the position of a scientist.

But why these two possibilities are not efficient/sufficient to handle the current reality? It seems that a need to understand the world should start from the students; they should not be presented to science knowledge as being something fundamental to their life. For many students, the saying "knowledge is power" is silent. Knowledge is the first step toward a citizen to be a "center of decisions", as it enables a person to be seen and recognized as having rights, giving him/her a voice and conditions to be heard. It is feasible students to "taste" knowledge as something attractive. If this occurs, a person does not need to delegate power to others: he/she becomes his/her own agent. When more people is educated, many can realize (and learn) their potential for agency; as the number of citizens increases, the process may guarantee the collective right of accessing knowledge.

As a response to these challenges, we propose the establishment of active methodologies, which can start a process of graduating a critical mass of teachers and researchers engaged in training citizens. This movement could occur naturally, without intervention from anyone. However, we live in a complex world, guided by the acceleration of time and the shortening of distances; for these reasons, it is important to act locally and fast.

In this scenario, the knowledge on Geology requires building a mental model of the long intervals of Earth history. Geology has the mission of reconstructing the succession of worlds shaped by the cyclic interactions of the Earth processes and the unimaginable quantities and varieties of living beings that helped populate the planet. Tracking the trajectory of the ball circulating around its star since billions of years ago, the existence of life forms has extensively changed the evolutionary picture of a formerly lifeless planet. The debate goes together with the evolution of Earth science knowledge. Gradually, the Earth's past has been recomposed, fragment by fragment, never by consensus, but under an always dynamic path, eventually subject to controversies. It can be argued that learning Geology or Geosciences is a way to build or to enhance the character of a person, precisely insofar as it leads us to conceive the uniqueness of each evolutionary stage and acquire a sharp critical vision of our own reality and the circumstances under which we live.

It seems that the most efficient way to achieve the objectives of this article is by the rapid multiplication of knowledge. To do so it would require the formation of a group of educators in science interested on to amplify awareness of the students about their inalienable rights as well as the importance of humans as agents facing natural processes. One of these students' rights is the right to know (in depth) the world we live in. If one takes into account the Earth's history and evolution, it is easy to see that the task would be better accomplished if Geosciences education is specially considered. Just questioning the facts and debating the causes which relegates most people to their peripheral status (in relation to knowledge, for example) we can give conditions for people to become agents of their own demands and to avoid many consequences of some irrational attitudes against natural environments.

Conclusions

The initial hypothesis about the relevance of the topic is correct: there is a need for rapid multiplication of knowledge. This will require more competent teachers and into a certain degree more awareness among them about Earth science contents. Some of the listed elements do illustrate that the task of graduating more teachers does not cover only scientific points, but it harbors economic, social and cultural issues. These were, a long time, permeated by dogmas, beliefs, 'truths' (that often faded away due to paradigm shifts), and myths that have become paradigms currently accepted, and confirmed by the systematic use of the scientific method.

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