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Earth System Science as a Critical Knowledge for Educating Geographers and Other Professionals to Interact With Earth

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Earth System Science as a Critical Knowledge for Educating Geographers and Other Professionals to Interact With Earth

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Abstract

Humans actively participate in the Earth System and interact with other Earth spheres, especially the biosphere. This paper intends to evaluate the relevance of Earth System Science (ESS) in undergraduate courses of Geography. The ESS conception has been conveyed in two subjects at the University of Campinas, Unicamp, Brazil, aiming to introduce a holistic view of the geoscientific knowledge, while stimulates a discussion about multidisciplinary, interdisciplinary or transdisciplinary programs. The discussion about the environmental consequences of human actions and possible effects of climate change that often permeate the news are examples of affinities among spatial analyses of Geography using the ESS integrative perspective. A broad collection of articles, reports and books retrieved from the specialized literature reveals the great potentiality of an ESS approach to enhance the tools available for different professionals for analyzing the geographical space and observing the complex relationship between nature and man. The society, or the world system, has been astonishing marked out by political and economic concepts and ideas. The integrated view of ESS, typically linked to the investigation of physical and human processes, helps to understand phenomena, which occur at various spatial and temporal scales, and therefore it contributes to build a more accurate view of the whole and the parts of the contemporary world. It seems that it is urgent the review of the Brazilian higher education curricula of Geography and other careers as biology and environmental engineering as well, seeking to expand the training of the undergraduates with a strong background of Geosciences. This proposal may have a multiplication effect both for scientific research and a better performance of teaching in basic education.

Keywords: Education, Geography, Earth Sciences, transdisciplinary studies, environment.

Introduction

> The story of the biosphere – and the fact that there is life on Earth – is the story of connections between living organisms and the nonliving factors of the environment (Sagan & Margulis, 1989:42).

Earth System Science (ESS) is a module of knowledge divided into two successive subjects offered at the University of Campinas (Unicamp) to students of undergraduate courses on Geography and Geology. The authors of this study are teachers (CDRC, JRSM, PWG) and one student (AEC) of Geography. The principal motivation for this study arises from a huge perception that many Geography students do not give enough attention to the subject because they understand that the concepts are more essential to a Geology course.

The broad impact of Earth System Science in understanding terrestrial phenomena that build and shape the spatial relationships studied by Geography has encouraged us to look for evidence and examples of outstanding contributions of knowledge related to ESS in the formation of a geographer. The quest may be extended to another professions related to the natural environment, such as biology, engineering etc. This paper aims to discuss the importance of the subject, and seeks to establish new basis for understanding ESS as playing an important role among the key subjects for professional training on Geography.

The Systemic View

The concept of systems is acknowledged by the scientific community from a long time: a set of elements which interact with each other and have some type of interdependency, as the solar system and many other systems which compose Earth. The pioneering study by Ludwig von Bertalanffy in 1932 on "The General Theory of Systems" was strictly based on the systemic concept (Christofoletti, 1979). The knowledge of systems has experienced fast advances, especially in recent decades.

Christopherson (2012) offers an interesting definition of systems that can be directly applied to Earth Sciences:

> "Simply, a system is any ordered set and interrelation of things and their attributes, connected by flows of energy and matter, distinct from the surrounding environment outside the system. The elements within a system can be arranged in a series or intertwined with each other. A system comprises any number of subsystems. In terrestrial systems, both matter and energy is stored and retrieved, and the energy is transformed from one type to another." (Christopherson, 2012, p.5)

A given system may comprise a number of sub-systems (Christofoletti 1979, Christopherson 2012). This important aspect of a systemic approach is in accordance with the complex interactions, at various scales, within planet Earth, its material spheres and their processes: atmospheric, oceanic, tectonic etc..

As a component of spatial analysis, the systemic approach has been used by geographers as a tool that allows a practical use of the general theory of systems; current research has reviewed and systematized the initial design, bringing out new ideas and applications. Christopherson's concept of systems (2012) brings together the notions of unity, interrelation, processes and flows, key ideas to understand Earth processes.

The subjects Earth System Science I and II use an integrative approach to relate contents of Human Geography and Geology with the intention of forming students' ability to understand concurrent (or somewhat conflicting) processes that occur on the planet and society (Carneiro et al., 2008). Details of characteristics of the Earth Science courses I and II are described by Carneiro & Goncalves (2010, 2013) and Carneiro et al. (2008).

Geography includes the flow of information also in the category of flows. Information is very relevant in the present period of human history since "science and technology, along with information, are at the base of production, use and operation of the space and tend to be its substrate" (Santos, 2006 p. 160).

The Gaia Hypothesis (Lovelock, 1979, 1991) can be used as an analogue for understanding what it is the Earth System and how the interactions do occur; this can justify that human/social relationships are components of a system, and can serve as well as a resource for understanding the role of man as a builder and shaper of the Earth System. The role has been put in evidence when impacts of human actions on the planet are analyzed. It also reveals a relationship between the notion of an integrated Earth System Science and the geographical spatial analysis.

In the scientific community, the conception of Earth System Science has induced a debate about the definition of objectives, knowledge fields, objects of study and also a specific perspective for viewing the knowledge practical application. We consider the holistic view of ESS as an important component to geography and therefore a relevant knowledge for any geographer.

Objectives

The research aims to analyze and discuss the role of the set of core knowledge about the Earth System Science and its importance for the formation of the geographer, in the view of the need for the geographer to know the "operation" of terrestrial phenomena and their influence on the construction and modification of the geographical space, which is, in essence, the object of study of geographers. The objectives comprehend the need to consider more and more the importance of the geographer to have a holistic view of space, a very important precept for Earth System Science, the growing interdependence of natural and human processes.

Research Methods

The research is inspired on a 16-years educational practice by two of the authors (CDRC, PWG), which have offered successive issues of subjects Earth System Science I and II. During this time interval many questions and comments about the relevance of Earth System Science in shaping a geographer have been arisen. The framework has inspired a literature survey whose results are presented in this communication.

The research activities consist primarily of bibliographic search and literature review. The organization of readings and analysis was divided into two fronts:

- Characterizing Earth System Science and the relationship between Earth System Science and the Geography System;
- Investigating the potential contribution of Earth System Science along the process of educating a geographer;

The number of titles from the recovered literature is very large as long as the focused aspects are quite broad; at this stage of investigation, only papers and books which deal specifically with the subject ESS+Geography have been studied. At a later stage it has been suggested to make a few interviews with graduates, to gather evidence about the relevance and validity of the conclusions outlined in this article.

Results

Earth System Science

The knowledge of Earth System Science is intrinsic to Geography and Geology. Pitman (2005) states that ESS ("Earth System" or "Earth System Science") means "different things to different people", factors that complicate the task of establishing a short definition as outlined here: Earth System Science – ESS – is the study of the Earth as a unique, integrated physical and social system. Pitman (2005, p.138) argues that the mission of ESS is to study the "operation" and interactions between human and "biophysical" systems:

> … [ESS] studies the functioning of, and interactions between Humans (including population change, economic growth, social change) and biophysical systems (including soils, hydrology, the atmosphere, ocean, cryosphere and ecology) via biogeochemical cycles (Pitman, 2005, p.139).

Human systems include changes in population and economic growth, as well as social change. The "biophysical" systems include a broad list of living

and non-living systems, as the soil, atmosphere, ocean, cryosphere and ecology.

It is essential to distinguish a systematic science from a systemic science. The central feature of a systematic science lies in the object of study, which consists of recognizing and determining common characteristics of specific elements and the groups formed by the elements. From the identification of common features, a researcher tries to group the elements to form an overall picture (Rojero, 2000). In contrast, a systemic science considers the object of study as composed by a set of interconnected elements that have discernible relationship to each other and form a coherent whole. It has been acknowledged that the human and natural systems obey to specific laws and this is a feature common to a system (Rojero, 2000). This author argues that:

> Taking into account that in the world is almost impossible to find objects that do not form part of sets of elements which maintain some kind of relationship, it is clear that if the premise is right, the world is made up of numerous systems that can be studied in a similar way, independent of the elements which compose them (Rojero, 2000, p.190).

The prospect of linking several, if not all, areas of science to study the "operation" of the systems comes from the ESS holistic perspective, a look that claims one to "see the whole", apart from a reducionistic one, which focus on separate parts. Pitman (2005) proposes this as a typical feature not only for ESS but mainly for Geography:

> I do, however, argue that there has been an explosion within the international community's effort in Earth System Science *independent* of any significant role or contribution from Geography. The Earth System Science community would likely fail to recognize names like Chorley, Dury, Davis, etc. because this new ''Earth System Science'' has emerged from mathematics, physics and biology. Thus, while Geography *has* made many important contributions, it seems it has not done enough to prevent the re-invention of Geography twice (Pitman, 2005, p.138, highlights from the original)

Johnston (2006) points that "Geography has a clear role within the academic division of labour, more intensively developed in some places than others because of local cultural and historical contexts (…) [because] Geography matters". So, he refuses Pitman's appreciation of what "human geographers might bring to geography-as-earth-system-science". The claim for an outstanding role to be played by geographers instead of being "replaced" by other scientists is therefore useless; probably, he argues, it is an evidence of some "inferiority complex" that should be avoided.

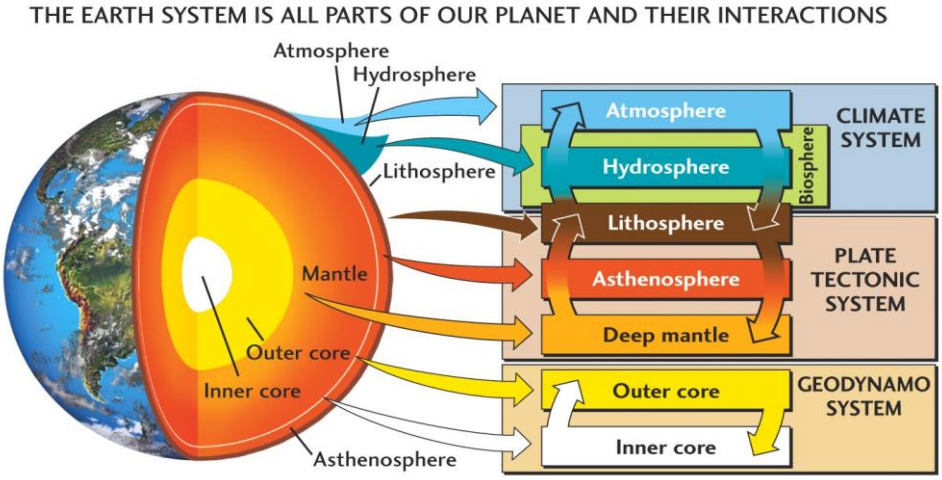
To understand Pitman's (2005) proposal for revaluating Geography and Earth System Science as systemic sciences, we tried to establish what would be the system itself and its constitution. Press et al. (2006, p.36) explain that, together, all parts of our planet and their interactions constitute the Earth System. The main system components are called Earth spheres: atmosphere, hydrosphere, biosphere, lithosphere, asthenosphere, lower mantle, outer core and inner core. Earth System is divided into three subsystems: (i) the climate; (ii) the tectonic plates; (iii) the internal geodynamo (Fig. 1). Nothing is mentioned on regard to human systems as specified by Pitman (2005). The definition holds elements linked to the study of the Earth itself; in other words, it refers to physical and natural aspects. One can argue that the book (Press et al. 2006) emphasizes components associated with geological studies, since it is an introduction to General Geology.

The proposal that Earth System Science can embrace not only natural sciences, but also human sciences may be somewhat revolutionary, but surely it is a conciliatory idea, because Earth is dynamic and human societies actively contribute to changes (Loon, 2001). Man is both an agent and a patient of the consequences of processes.

Transforming Actions of Man in Earth System

Rooted in natural and physical issues that arise from the relationship of humans and the planet, the concept of Earth's operating mechanisms currently involves human hands. Humans and their societies do not "control" Earth, but they have a profound influence on the biosphere and the terrestrial landscape. The influence can be regarded as very significant for the fact that it is done by one among millions of species of life on the planet (Williams Jr., 2000). The interactions among men that result in the extraction of mineral and energy resources, tourism and accelerated consumption undoubtedly converge in consequences for many of the variables that make up the entire Earth system. They have degraded the biosphere in a very aggressive way, as brought by Richard S. Williams Jr. (2000). Beyond the biosphere, Williams Jr. also recalls the transformative power of human actions on the hydrosphere and lithosphere.

Figure 1. *Original Categories of Systems that Make Up the Dynamics of Planet Earth: Climate, Plate Tectonics and the Geodynamo*



Source: Original illustration in English Press et al., 2006

The first human activity that acquired magnitude to make major changes in the surface of the planet was agriculture. Williams Jr. (2000, p. 311) brings many negative aspects of human actions on the Earth System. Taking agriculture as the first parameter for diagnosis, there are many examples of consequences of "intentional" changes, such as deforestation and habitat destruction, and unintentional changes, such as erosion, soil salinization and lowering of water table in many regions; the use of chemicals by "modern agriculture" as herbicides, insecticides and fertilizers to increase production. On soil erosion, the author also brings out the amount of arable land and topsoil lost by increasing agricultural production towards greater food production.

Conclusions

The results presented in this research highlight the broad benefits from, or even the need for, more intensive treatment of Earth System Science (ESS) to be taught in undergraduate courses of Geography. ESS, as a not-so-young emergent field of knowledge, introduces an integrated perspective if viewed as a connection between the investigation of both physical and human processes. The ESS approach helps to understand many phenomena at various spatial and temporal scales. The integration of ESS with Geography happens in a time when the awareness of the need to respect the natural dynamics of Earth System is growing. The human capacity for observation of phenomena has expanded exponentially, along with the ability to promote landscape change and to predict responses and consequences that will impact both natural and human processes.

In conclusion, a revision of the curricula of Geography for the Brazilian higher education is necessary, and this should be extended to other careers as biology and environmental engineering as well. This can contribute to strengthen the training of the undergraduates with Geosciences background. This proposal may have a multiplication effect both for scientific research and for a better performance of teaching in basic education.

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