Using time by students and teachers: obstacles and explanatory register in coupling biology-geology

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Abstract

In this paper, we shall discuss, theoretically, obstacles and explanatory register to understand how to build a problem in science, especially when using time in coupling geology and biology. We shall also explain time in its geologic and didactic approaches. We try to understand the incommensurability of time and its infinitesimal division when using it to demonstrate a relationship between biology and geology. In literature, time is divided into three types: deep, sagittal or cyclic. Which types of time is used by students and teachers? Educationally, we seek to answer these questions: which obstacles students and teachers are faced with when they use to a type of time? Do students and teachers work in the same explanatory register when they relate time to other concepts?

Keywords

Geology, Biology, time, explanatory register, obstacles

Résumé

Théoriquement, nous explicitons les concepts didactiques en jeu; les obstacles et les registres explicatifs pour comprendre comment construire un problème en sciences, spécialement, lorsqu'on utilise le temps dans le couplage biologie-géologie. Nous essayons de comprendre l'incommensurabilité et la division infinitésimale du temps lorsqu'il est utilisé dans la mise mettre en relation de la géologie et de la biologie. Dans la littérature le temps s'explique par l'articulation entre trois types de temps;

profond, sagittal et cyclique. Lequel de ses trois types de temps est-il mobilisé par les apprenants ? Pour ce faire, nous répondons aux questions suivantes : Quels sont les obstacles à l'usage du temps par les apprenants ? Est-ce que les élèves et les enseignants travaillent le même registre explicatif lorsqu'ils mettent en relation le temps et d'autres concepts ?

Mots-Clés

Géologie, biologie, temps, registre explicatif, obstacles

Introduction

The two great revolutions in geology were marked, respectively, by the discovery of deep time and the theory of plate tectonics. However, despite the importance of the discovery of the time that has shaped the backbone of geology, and also biology, few researchers especially in the didactics of science, focused on its teaching. If epistemology allows a reflection on time and the obstacles that prevent humans from managing it, the capabilities of students to integrate the concept may not be adequately formed to explain natural phenomena in their temporal dimension. The difference between our intuitive understanding of time and slow geological or biological processes seem to be insurmountable. In the theory of the earth, Hutton says that "*time, which measures all things in our ideas, but often eludes our purposes, is immeasurable and intangible in nature*" (in Gould, 1990). Would the immateriality of time be inaccessible for the learner to explain the process of certain natural phenomena? In biology or geology, natural phenomena can take a second, a month or millions of years. For example, an earthquake can last only a few seconds while the tectonic phenomena that preceded it occur over a few million years. The formation or destruction of a mountain requires a reflection on the vastness of the duration, characteristic of this phenomenon. How is this slow geological or biological process understood by students or teachers when compared to the temporal scale? To understand how students or teachers acquire the vastness of time or its infinitesimal division, we rebuild the explanatory register in which our sample has used time, and therefore the obstacles to manage its incommensurability.

To explore these questions related to time, we expose its geologic and didactic approaches before to explain the concepts of our study (obstacles, explanatory register). We present also the method of our investigation in order to understand how students and teachers use time to explain natural phenomena.

The Geologic Approach Of Time

To decrypt the earth history, several methods are used in which time was a tool for an understanding based on the principles of stratigraphy (Le Pichon, 2003). The principle of horizontality allows geologists to observe a set of vertical stratigraphic layers as a chronological record of the geological history of a region. However, stratigraphic principles cannot be used to determine the relative age of geological layers, largely displaced geographically, so geologists return to fossils. Already, Smith in 1799 correlated the succession of faunas from different outcrops of rocks. Later, this approach allowed geologists to build a geological scale.

For centuries, geology did not exist as an independent and recognized discipline, and if this is still the case today it was due to paradigmatic changes in natural sciences, and subsequently in the field itself. For example, the discovery of deep time allowed us to revisit the historical aspect of geology and to break with the static view to develop the functionalist aspect of earth sciences. Indeed, the main reason for the neglect of geology as a historical science is linked to a recurring argument that makes it a "derivative" whose methodology is provided by physics (Bucher, 1941; Schumm, 1991). The development of physics has made it a model of science (Mayr, 1998) supporting materialism, especially during the thirties, in exchange for a model supporting vitalism. For many scientists, geology is a historical science not a derivative of physics. Far from simply taking up and applying the logical techniques of physics, geological reasoning has developed its own distinctive set of logical procedures (Frodeman, 1995). The 20th century was marked by a certain ignorance of geology as an independent science, which forged its concepts through interaction with other disciplines and with which it cannot interfere. This legacy goes back to Lyell, who considered geology derived from physics, and tried to use physical methods to explain events or natural phenomena. Indeed, the impression of geology as a derivative science has sometimes been reinforced by episodes in which geology and physics have interacted (Dodick & Orion, 2003a). To reduce geology to such a physical approach has limited its historical aspect of interpretation, but also its systemic methodology that contributed to explain the planet (Celal Sengor, 2005). By oscillation between the historical aspect and the functionalist aspect, geology has approached more than biology itself "torn" between "law and history" (Gayon, 1993). This history, as specified Orange-Ravachol (2012), is nothing more than elaborate consideration of time.

As for relative dating, it has to put in order the strata temporally. Geology is in its essence a historical science that focuses on the reconstruction process that affected the earth or the biosphere. This reconstruction, based primarily on the principle of uniformitarianism, was explored mainly by Lyell (1797-1875) in his work "the principles of geology" (1830-1833), defined by Press & Siever (1998) as "*the geologic processes we see in operation, as they modify the earth's crust today have worked much the same way over geologic time*". Exploring the methodological principle of geology, Hutton and Lyell helped to understand the types of time. It is now possible to know the age of the earth but it's difficult to understand incommensurability of time even by scientists. The immensity of time, but also the events that took place in terms of durability, would not be an obstacle to the acquisition of biological or geological knowledge but students can create their own metaphor to understand a history of events (Ritger & Cummins, 1991). So can students represent better time when they explain natural phenomenon while the direct observation?

When geologists have ranked most fossil layers in a geologic time scale in the 19th century, it produced an inevitable feeling "*of vistas of time stretching far beyond the scope of human history*" (Burchfield, 1998). Nevertheless, the magnitude of this scale, although it allowed the acceptance of deep time as a concept, was limited due to the lack of "action" to determine the age of the earth. New measures involve physical geology which is embarrassing; already, the calculation of Kelvin was, as stated by Dodick and Orion (2003a), a serious assessment of the Darwinian interpretation. The "*deep time*" could be a key to the theory of natural selection, operating changing only through the vastness of geological time (Burchfield, 1974). Darwin spent years to demonstrate and argue the evidence of his theory, while proving the immensity of time, adjusting the rate of the new scale evolution as estimated by Wallace and Huxley could have solved the problem of natural selection. The contribution of geology, with the concept of "*deep time*" had an impact on biology, given the slow variation of life forms proved by the long time required to sediment deposition.

Time as a multidisciplinary concept and will be studied in geology, and also in biology, as a key concept to understand the phenomenon process. For this reason some research, especially in the educational science, focuses on its using by students or teachers.

THE DIDACTIC APPROACH OF TIME

At the conference, "*Project 2061*" which was held in Washington, DC in April 1988, participants identify the most important earth science concepts. Among the concepts identified "*The earth's natural processes take over instead periods of time from billions of years to fractions of seconds*" (Mayer & Armstrong, 1990). This orientation to time seems to be needed to understand many scientific fields, including geology and biology. The most obvious problem is the cognitive understanding of geological time by students. Thus, several studies in educational geology focused on the practical aspects of teaching geological scale, and hence the time (Rowland, 1983; Ritger & Cummins, 1991; Monchamp & Sauvageot-Skibine, 1995). Unfortunately, the teaching of geological time has never been critically assessed taking into account the pedagogical or didactic literature. Not surprisingly, some researchers have done several psychological researches on time cognition, including those by Piaget on cognitive psychology. However, this mostly concerns the time conditioning and perception (Fraisse, 1982). Friedman (1978) argues that time is explained in cognitive ability to determine the temporal relations between events. This definition incorporates the main search of Ault (1981), which is used as a unit of geological time in which we can distinguish events. This dating allows a reconstruction of the historic transformations that have occurred over time. It should be remembered that the work of psychology about time tend to restrict scales in years, while the geological time shows a level of abstraction difficult to conceptualize.

Ault (1982) caught up and showed that time itself does not pose a problem for students in class; while on the field students find it difficult to explain the phenomena in a temporal framework. Ault interviewed students about the reconstruction of a geological series and showed that they organize geological time on a relational level. Ault's analysis is rooted in a Piagetian theoretical framework in which the understanding of time by children is closely linked to the movement, a physical concept. This allowed him to conclude that most children in the classroom were able to solve problems with the skills necessary to understand geological time. However, on the field, the same children find it difficult to solve the same problem. If the geological knowledge built over time through observation static entities concept, formations and fossils (Frodeman, 1996), is accused of Ault influence by the work of Piaget, especially in his book "six psychology studies" on the concept of time, which in this case is closely related to the concept of movement, Ault (1982) himself admitted that the concept of movement only multiplies the variables to understand the students' difficulties when they should focus their efforts on the immensity of time that could impede its acquisition.

Asked about the process, Le Pichon states that corresponds "*to everything that the Earth is not the same now as it was there one minute or 100000 years or 1 million years*" (Orange, 2003). Despite its critical pedagogy while there is very little interest, didactics focused on the understanding of time by students (Gohau, 1995). Several studies on the origin of the earth (Marques & Thompson, 1997; Noonan-Pulling & Good, 1999), the origin of life (Orange-Ravachol, 2003) and biological crises (Boughanmi, 2009) demonstrated the students' difficulties to understand geological time when they mobilize knowledge to explain events or natural phenomena. Several studies in education of geology lead the work on time to three components:

- The deep time, large time scale, in which geological phenomena or events occur. The discovery of "deep time" exists among the scientific revolutions that have changed the status of the human being as his existence for thousands of years has only been the last millisecond of the scale. This revolution has answered some other riddles in disciplines like cosmology, biology.
- The cyclic time inscribe the earth in a succession of identical cycles. Each cycle consist of three phases gradually succeeding. Every phase is the cause of the following one. A destruction phase in which reliefs disappear under the action of erosion. The strata

materials will be deposed in the ocean basins, it's the deposition phase. And finally, under the mass of strata, a heating phase leads to melting rocks and after mountain emergence where previously there was an ocean.

- The sagittal time inscribe the earth in a progressive history though not irreversible. The process of the natural phenomena or events follows up a unidirectional history that occurs only once.

The Explanatory Register

Scientific research and science education are based on modeling (Martinand, 1995; Orange, 2000), but without treating the theoretical register in detail, and the debates that it generates, we use the definition of registers advanced by Orange (2000). The empirical register (or "*worlds of facts and phenomena*") consists of phenomena explained by the model; it corresponds to facts and phenomena that we must take into account or explain when we study a problem. The register of models (or "*world explanations*") consists in making constructions due in light of certain facts and phenomena of the empirical register. The explanatory register is "*the world that gives meaning to the model and can handle it*". "*Thus construed, the word 'explanation' and its cognates are pragmatic terms: their use requires reference to the persons involved in the process of explaining. [. . .] Explanation in this pragmatic sense is thus a relative notion: something can be significantly said to constitute an explanation in this sense only for this or that individual*" (Hempel, 1965). Later Salmon (1971) using a statistical model has proved that an explanation is not an argument, and there is a difference between explanation and prediction. In this debate, we must remember that "*the explanation refers to phenomena that have already taken place, while the prediction refers to phenomena that have not yet occurred*" (Galavotti, 1990). We consider that an explanation in biology or in geology oscillates between laws and history. Today the philosophy of science recognizes a multidisciplinary development in which an explanation needs conditions of possibility in order to understand phenomena. Drawing on the work of Martinand (1995), Orange (2000) and Orange-Ravachol (2003) built the following modeling diagram by which the explanatory register is established as more encompassing.

Chart 1

Empirical register	linking	Register of the models
Explanatory register		

The different registers involved in the modeling (Orang-Ravachol 2003)

Working with examples from functionalist and historical geology, Orange-Ravachol (2012) showed that the registers can be rebuilt and also the relationships between the empirical register and the register of models. The figure of modeling is used to reconstruct different registers applied by students or teachers to explain some geological phenomena. If the empirical register and the register of the models are not given, but rebuilt, we must also consider the explanatory register. Indeed, linking the empirical register and the register of models is done in a register of "*explanatory references*" (Canguilhem, 1988). Basically, according to Hempel (1965) we can explain a phenomenon when our knowledge provides sufficient logical information that could have been used to explain the same phenomenon before it is observed. Thus, Hempel, recognized the relationship between explanation and understanding, but he said the notion of "understanding" and "understandable" does not belong to the vocabulary of logic and they refer more to the psychological aspects of the explanation. So what is explanation referring to didactic of science? As asserted by Orange (2000), the elements of the explanatory register, although very difficult to implement, are based on the relation between empirical constraints (empirical register) and the conditions of possibility (register of models). The conditions of possibility are a necessity for the explanatory register. In fact, the notion of constraint is often associated to the empirical record and the necessity to register models. Should we go back to the evolution of the didactic concepts developed by the CREN (Research Education Center of Nantes) with a reflection on elements to build registers?

In this paper we try to understand in which register work students and teachers when they use time to relate biology and geology.

The Obstacles To Historical Interpretation

The history of science has been marked by a series of "*paradigm shifts*" (Kuhn, 1962) that have influenced the explanation of the universe and its components. We only mention the Copernican-Galilean redefinition in which the earth is no longer the center of the solar system and the Darwinian revolution in which man lost his narcissism. Among these paradigm shifts in the history of science, the "deep time" discovery is less often mentioned whereby the human represents, metaphorically, the last link of the geological scale. Indeed, the temporal revolution has been neglected for several reasons: geology is considered as a field science which limits its theoretical field, the difficulty to experimentally validate stratigraphic data and gaps shown in the fossil record. Therefore, the nature of "deep time" itself precludes direct observation (Frodeman, 1995, 2000). In Bachelardian framework, we assume that the advancement of geology and its history has been hampered by many epistemological obstacles: flat earth, immobility, and creationism. Indeed, "*when seeking the psychological conditions of the* *science progress, one soon comes to the conviction that it is in terms of obstacles that must be built a problem in the scientific knowledge. And it is not considered external obstacles, such as the complexity and fleeting phenomena, nor to blame the weakness of the senses and the mind: it is in the act of knowing, intimately that appears in a sort of functional necessity, delays and disorders. This is where we show the causes of stagnation and even regression, this is where we detect inertia causes called epistemological obstacles*" (Bachelard, 1938/1970). Through the example of time, we try to identify how certain obstacles have been overcome in history, mainly by the historicity of geology and time incommensurability.

Science education has borrowed much from Bachelard's epistemology and will continue to do so long as it remains worthwhile. Bachelard says in his famous text that "*the concept of obstacle can be studied in the historical development of scientific thought and education practice*" (Bachelard, 1938/1970). Moreover, we treat geology historicity theoretically, while limiting the concept of time, and empirically by to students' investigations. For Bachelard, it is necessary to waive prior knowledge to change scientific culture and accept a real break between "sensitive knowledge" and "scientific knowledge". Indeed, the evidence brought about by sensitive knowledge is not rational, but expresses a deeply irrational intimate satisfaction. Practically, this means that, to think scientifically, we should never stick to the immediate object, the first observation, but give as their principle method of questioning. Besides Orange (1999) affirms in that in geology "*the real is not limited to laboratory experiments: we must add the fieldwork*". In this perspective, learner should provide highly relevant and restructure its designs on the same principles that govern the development of scientific knowledge, but also the general culture, which approximates learner to knowledge. "*From the scientific education of the school, we accept the facts; forget the reasons and thus the general culture are delivered to the empiricism of memory*" (Bachelard, 1949/2004). Didactics often connect misconceptions to obstacles, particularly the obstacle "*may designate the step from common sense and scientific knowledge*" (Fabre & Orange, 1997). This break can be achieved by building problems, which do not arise from themselves, and the overcoming of epistemological obstacles that might be sensitive or common knowledge present in the form of learning designs. Any understanding of the earth history was hampered by some epistemological preventing new ideas in that field. What are the obstacles facing students and teachers to explain natural phenomena in a temporal framework?

The Research Questions

The special qualities of time could complicate the logic of its use by students and teachers. Therefore by linking some concepts related to biology and geology, we will identify the explanatory register in which the type of time is referred to by students or teachers. So to understand this relationship between more than scientific concepts, we have to answer to three questions built in a temporal framework:

1. Which types of time used by teachers when they relate time to natural phenomena and what are the obstacles faced by them in coupling biology-geology?
2. How did students use time when they relate it to others concepts and what are the obstacles faced by them in coupling biology-geology?
3. Did students and teachers work in the same explanatory register when they link natural phenomena to the time?

Methods

To limit our research, we will choose three phenomena; earthquakes as a functionalist problem, mountain formation and biological crises as a historical problems. Workshops, which are the subject of this paper, were preceded by a textbook analysis and questionnaires about the three phenomena and then followed by discussions. We expose in this paper just workshops.

Samples and data collection

This research has taken place in Tunisia with students and teachers. Our sample is composed of 58 teachers in the last year of the Master's biology-geology degree and 47 students in 3rd grade science experiments (17-18 years old). During their four-year degree teachers acquired a strong background in natural science and they pass the CAPES (diploma to teach in secondary school). Those who succeed in CAPES will be trained in pedagogy and didactics of science.

Data collection with teachers was conducted by a didactician assistant who is accustomed to methodological research contexts. The students themselves were followed by a professor of biology-geology; she also followed an extensive training in science education. We explained to them the instructions to lead the inquiry.

The research procedure

We asked our sample to relate concepts and to fill tables. For the students, they will fill tables 2, 3 and 4. Teachers will fill table 1. Expected answers are presented in tables 1 to 4 in order to compare them with the answers of our sample. This qualitative analysis will be completed by a quantitative comparative (table 9) in which we summarize obstacles referring to using time by teachers and students.

The teachers' Workshop

In table 1 we present some relationship between all concepts studied in this paper.

TABLE 1

Expected teachers' relationships between concepts based on literature

	Life	Earth	Species	Geological scale
Time	Sagittal time : chemical reactions Deep time : evolution; cycles and biorhythms	short phenomena (earthquakes, eruptions) long phenomena	Origin of Life History of life, Historicity story	Sagittal time, deep time, Time rhythmic cyclical phenomena (rock cycle)
Earthquake and tsunami	Disaster, damage, extinction of certain species (insects)	internal and external geodynamics, Energy Transformation	prediction of earthquakes and tsunami, avoid disasters	long geological process (subduction) earthquake in a short time
Data	traces of a Life evolving serve as benchmarks	Geometric relationships of phenomena allow indicia benchmarks	History of space	Relative dating Absolute dating
Convergence: *Subduction, Collision*		Construction of continents and reliefs, global dynamics of the earth	History of space and earth	Phenomena that take place over long periods of time, cataclysmic
Coupling of biological and geological events	Life affects earth	Earth affects life	Extrapolation from the present to the past or the future	Time : slow and rapid changes

Source: (Boughanmi, 2009)

The students' workshop

Following a test with eight students, it turned out that there is confusion between "life" and "living beings" which can lead to a philosophical debate about this concept. So we decided to merge the two columns into a single column. We also asked our colleague to organize the workshop it in three phases in order to collect more information's. The answers of students are also classified and compared to those expected.

First phase: Each student fills in the following table.

TABLE 2

Expected students' relationships between natural phenomena based on literature

Relationship	Life	Earth	Geological scale
Earthquake and tsunami	Disaster, damage, extinction of certain species (insects)	internal and external geodynamics, Energy Transformation	A long geological phenomenon (subduction), followed by an earthquake in a short time
Mountain formation	History of my earth	construction of continents and reliefs, knowledge of the global dynamics of the earth	phenomena very long periods, punctuated by events Cycles
Biological crises	Life affects the earth My place to understand what happened	The earth affects life	Time : slow and rapid changes

Source: (Boughanmi, 2009)

Second phase: discussion of responses in Table 2
To lead them answering in an interdisciplinary framework, our colleague, who investigating, has animated a discussion between students about biological crises before they fill Tables 3 and 4.

Third phase: each student completes both Tables 3 and 4. In table 3 we expose expected answers relating time to some natural phenomena.

TABLE 3

Expected students' relationship between time and natural phenomena based on literature

	Earthquake and tsunami	Moutain formation	Biological crises
Time	Long geological phenomenon (subduction) earthquake in a short time	phenomena very long periods, punctuated by events cycles	slow upheaval; brief changes

Source: (Boughanmi, 2009)

In table 4 we expose answers about relationship between time, life and geological scale basing to literature.

TABLE 4

Expected student's coupling time with earth, life and geological scale based on literature

	Living-beings	Earth	Geological scale
Time	Short time (chemical reactions) to long time (Evolution) anthropomorphism period of my life, leading to death, my place on the earth, my past, my future	the shortest phenomena (earthquakes, eruptions) to the formation of "Pangaea" through geological cycles	Sagittal, cyclic, deep

Source: (Boughanmi, 2009)

Data analysis

Noting that for our sample, a response can contain more than one idea. So to analyze data, we classify in the same category the responses that refer to the same explanatory framework. To answer to the 1st question of our study we analyze table 5. To give interpretation to the responses of 2nd question we analyze tables 6, 7 and 8. To identify in which explanatory register work teachers and students, we expose in table 9 the comparative analysis with percentage.

We note that tables 5, 6, 7, and 8 are built from a complete analysis of all responses without giving a percentage because we identify a lot of information in one answer. So statically, it's not possible to quantify. We expose in annexes (tables 10, 11) some responses of students and teachers which are more representative in our categorization.

RESULTS OF TEACHERS' WORKSHOP

To answer the 1st question of research, we summarize, in table 5 the majority of relationships mobilized by our sample and we identify difficulties when they use time to link biology and geology.

Anthropomorphism favored using sagittal time and evolutionism favored using deep time

The majority of teachers limit the life-time relationship or time-living beings to life-expectancy. This short time dimension is bounded within birth-death; life begins with birth and ends with death. In this case, the fate of living-beings, conditioned by the birth-death duality refers to a short period, teleology and anthropocentrism. However, some teachers who adhere to the theory of evolution took into consideration the evolution of life over time, but that time does not exceed punctual event (birth, death)

TABLE 5

Relationships between concepts based on the teachers' responses

	Life	**Earth**	**species**	**Geological scale**
Time	anthropocentrism, short temporel dimension, evolutionism	Slow geological phenomena, history of the earth	Age, fossilization, evolutionism, determinism	determinism, precision, dating, eras
Earthquake and tsunami	Catastrophism, anthropocentrism, destoryed ecosystem, negative thought	catastrophism, anthropocentrism, geomorphology, mecanist, tectonic	Threat, catastrophism, negative thinking	Punctual geological phenomenon, no long process
Data	relative, absolute, precise	Fossils, strata age, relative dating, history of the earth	Absolute, relative, fossils, fossilization, age	Fossils, dating, reconstitution of the earth
Convergence: Subduction, Collision	Undetectable, independent	perceptible geomorphology, subduction, collision, volcanism	environement, adaptation, species extinction, finalism	Deep time
Coupling of biological and geological events	Global warming, recycling, non-renewable energy	biogeochemical cycles	Organic and inorganic matter, teleology, anthropocentrism, biological crisis	Biological crisis, evolution, dating events

or centuries. Generally, teachers work in two explanatory registers; creationism and evolutionism. Some teachers exceed the short time (age, birth, death ...) to work over a long period of time, making geological or biological processes, such as fossilization and the history of life possible. Some teachers think that the immensity of time makes it possible for certain geological phenomena to occur; others have discussed the evolution of the earth over time or very long geological rhythms. It seems that "life" incites teachers to work in an anthropocentric frame not exceeding the life of humans who are confined to a few decades.

Setting life-time relationship or time-earth shows that teachers' adherence to the evolutionism does not stop them working in disparate registers, each one associated with a type of time. The sagittal time relatively short, is related to teleology, anthropocentrism, determinism and creationism. Deep time is necessarily linked to evolutionism. Noting also that the relationship time-biology brings teachers to mention in most cases a sagittal time while linking time-earth bring them back to deep time.

Catastrophism without referring to the historical context of a phenomenon, geomorphology related to sagittal time and tectonic register refer more to deep time

The majority of responses refer to spectacular catastrophism; death, danger and destruction of buildings. In fact, teachers only retain the negative impact of the earthquake, it is said to be harmful to human and not as energy accumulated over time. The human being is again at the center of the teachers' explanation, his life is in danger. Some teachers referred to the extinction of some species following a disaster such as the tsunami, which is a result of a natural phenomenon. The destruction of ecosystems within the biosphere and the "annihilation of the shelter of life" may cause sudden extinction. Bearing in mind the duration of the phenomena and their consequences mentioned, we can say that teachers mobilize a short time (sagittal time). The position of the human being seems to be central in this explanation; this anthropomorphism pushes teachers to work in a sagittal time.

Energy conversion, the result of internal and external geodynamic, in geological phenomena or events over millions of years, has not been mentioned by all teachers. However some teachers resort to concepts related to earth changes, but in the short term, and therefore, those teachers work in a more destructive geomorphologic framework; they evoke the destruction of soil, surface deformation ... etc. The change in the structure of the earth is the internal geodynamic which takes millions of years. Some teachers work more in a tectonic framework and their answers refer to the theory of plate tectonics. Tectonic geological processes are only possible in a relatively long time. It seems that teachers mention more perceptible phenomena (earthquakes, volcanoes... etc.) without referring to their historical context.

We note that teachers work in an anthropocentric framework - when they focus on the concept of "life". Their explanations refer to catastrophism - when they are interested in "earthquake" concept. The majority of teachers think that danger can affect all living beings. The word "risk" is more related to the "earthquake" concept; a recurrent phenomenon that teachers have neglected is the slow geological process that precedes it. The spectacular catastrophism evoked by teachers reinforces their negative thinking. Tectonic explanations refer more to deep time.

The history of the earth: fossilization versus calendar time

For some teachers, the origin of life is a phenomenon that has raised several questions including the date of its emergence, estimated by some teachers at 3.8 million years. Absolute dating gives information about the appearance of life on earth, while fossilization provides a benchmark for the determination of different ages and eras. Their explanations seem to oscillate between two poles: historical science (paleontology) and experimental science (method of determining the age of fossils). However, we do not find any teachers' reference to the usefulness of fossilization in the reconstruction of ancient earth, and therefore extrapolation of current studies in geology as far back in time as possible to understand the evolution and deformation earth.

The oscillation between deep time and sagittal time appears in the relationship between abstract time, built for social practices such as calendar, and the concrete time, which is itself a constructed field that allows measuring the extent of geological time from seconds to billions of years. Sagittal time leads teachers to work in an anthropocentric framework. The strata age allows them to mobilize deep time in a tectonic explanatory framework. In biology, the origin of life, meanwhile, is another large temporal dimension which refers to evolutionism.

Environmental register: when geomorphology and tectonic favored using deep time

Although the concept of earth and its large-scale changes are directly linked with convergence, its relationship with concepts is not straightforward. Linking convergence and life seems to be implied; the majority of teachers think that they are two independent phenomena, while mentioning that the convergence can affect life. The consequences reappear when linking the convergence and the living beings; however, we find anthropocentric and finalist ideas, the fate of the living being is his death. They also mention concepts which refer to environmental education, ecology or the theory of evolution.

Some teachers focus on the consequences of convergence in a tectonic explanatory framework, without explaining the slow geological processes (subduction, collision and the formation of mountain ranges) related to mobility. In a global context, teachers explain the dynamic aspect of the earth and are interested in geomorphology; the topography of the earth depends on the convergence.

We also note that teachers mobilize notions on the distribution of living beings in geographical space and also fossil existing in both continents African and American. They think that this distribution also depends on geological phenomena such as convergence. Relationships advanced by the majority of teachers refer to short time (ecology) and to deep time (biological crises). Geological phenomena contribute to the disappearance of living beings, the release of ecological niches and therefore more likely to give the appearance of new species. These phenomena are relatively slow.

When they use sagittal time, teachers explain phenomena in a finalist, an environmental or an ecological register. When they use deep time, teachers' explanations refer to tectonics, geomorphology or species extinction.

Coupling biology-geology: environment as a unifying problem

We note that coupling biology-geology refers, primarily, to environmental problems such as the greenhouse effect, global warming or recycling. The environmental education is an interdisciplinary crossroads of biology, geology, chemistry ... etc. Organic and inorganic chemistry and biogeochemical or geochemical cycles are based on the study of recycling. The concept of recycling could be treated in other didactic research. The non-renewable energy discussed here is a current problem that the world is faced with while trying to find solutions. Some teachers specify that minerals belong to the inert world and to the living world. The teachers work through the induced cycle's material (nitrogen cycle, carbon cycle) and refer to a cyclic time.

In an evolutionary context, the disappearance of living-beings is considered as an event, and not as a biological phenomenon due to a biological crisis and geological variations. This duality event/phenomenon should be studied again and its direct relationship with the duality sagittal time/deep time, so that the event can span a relatively slow time. It also seems that the fate of living beings which refers to teleology is still maintained by some teachers.

A chemical reaction takes a few seconds while recycling and climate change may extend over a very long time. Always the short time is referred to in teachers' responses even if the latter adhere to today's scientists' evolutionism.

Analysis Of The Students'workshop

To answer the 2nd question, we analyze the three tables filled by students before and after the discussion about biological crises.

Table 6

Coupling scientific concepts based on students' responses

Relationship	Life	Earth	Geological scale
Earthquake and tsunami	Extinction, extinction of plants, danger, dramatic dooms, anthropocentrism	Tectonic, wrinkling, breaking strata	Redundancy, hour, day, short time
Mountain formation	Geographic space, naturalism, anthropocentrism	Folds, fault, break, geometric shape,	Centuries, eras
Biological crises	Animal extinction, thought	Catastrophism, tectonic	noncyclic

Catastrophes is especially related to a short time

The concepts of life and living in connection with earthquake induce students to mention concepts relevant to spectacular catastrophism and anthropomorphism. Disappearance, destruction and death are the consequences of an earthquake, perceptible phenomenon that lasts only a few seconds, the geological process that precedes them can last millions of years. It seems that an earthquake always refers to sagittal time whereas students think only of what is triggered by the earthquake, the wave propagation and the bustle of people. For some students who work in tectonic framework, an earthquake may be the result of an active fault or plate movements. However, there are comments that are directly related to what is commonly thought, especially as related in some stories; the opened earth swallowing humans. Can we pass a mythical obstacle induced by a story? Especially since this story deals with earthquakes and indicates that the time to swallow living beings is very short. It is interesting to review the usefulness of a narrative in the explanation of certain phenomena or events to understand the immensity of time.

Formation of mountain, as an artificial image, is related to a relatively vast time (centuries or eras)

The formation of mountain is a necessity for humans because according to some students, it provides a natural balance; greenery, wood ... etc. This positive thinking of the forests' role, in general, refers to naturalism associated with our life. The concept of "geographical area" is recalled in this naturalistic setting, but the geometric shape rather refers to a mathematical framework. It also appears that the artificial image of the construction of houses, which is in itself an element of the earth, is also present as part of the explanatory framework of the mountain. One may reconsider the concept of space and the extended mountains through the study of the earth explanation. Whatever, the register of time, in which the student works, is relatively vast and no more than centuries or eras? Is it a psychological obstacle to conceive the immensity of time? In what follows we identify the obstacles to linking biological crisis with the living, earth or geological scale.

If a biological crisis may promote the evolution of living beings, students view it as a threat. The concepts of "disappearance", "extinction", disaster, and "crisis" let students refer to a negative thought of biological crisis. This limits their thinking rooted in an evolutionary current. However, students have attributed the crisis to two causes; tectonics and catastrophic, but we do not see the relationship between the core of the earth and the crisis. Other students believe that biological crisis limit the possibility of mutation considered as the main origin in the emergence of new species. We do not see how an intermediate form, for example Archaeopteryx, may limit the evolution of species. We estimate they think that an intermediate form can have multiple classification criteria; feather, beak... etc., so it does not give an opportunity for other species to grow.

Students have not gathered enough information, and we propose to conduct a scientific discussion with them, bringing elements to further explanations of the phenomena.

TABLE 7

Coupling time to natural phenomena based on students' responses

	Earthquake and tsunami	Moutain formation	Biological crises
Time	Determinism, short time	Long time: eras	Determinism, short time, accurate time

Which types of time students mobilize when they relate it to natural phenomena?

In most cases, the time used by students is limited to a few centuries. Determinism, which originates in a religious dogmatism, reappears in answers on the accuracy of the crisis cycle. The causes of these crises are predefined in the history of our planet. For all students an earthquake or a biological crisis occurs in a short time and is a phenomenon in direct relationship with human fate. Anthropocentrism remains one of the toughest obstacles to remove. Moreover, the formation of mountain (not cyclic for them) is a phenomenon that occurs within a few centuries. The register of time in which students work is very short, given the slowness of geological or biological processes of the phenomena.

TABLE 8

Coupling time with earth, life and geological scale based on students' responses

	Living-beings	Earth	Geological scale
Time	Evolutionism, decade biodiversity, extinction,	Earthquake, few seconds Geomorphology, millions of years	Years, eras

Evolutionism framework referring to deep time

When students work in an evolutionary framework, in most cases they refer to a deep time. The diversity of living beings or their extinction rather requires a relatively short time. The earthquake is referred to mainly in seconds; students only take into account its outbreak and a maximum of a few hours' panic before the event. Some students talked about redundancy and prediction after the earthquake. In general, the time does not exceed years or eras, as it defines "*the formation of the earth and the continuity of life were formed in few years*". Is it a psychological obstacle that hinders our awareness of the immensity of time?

Types Of Time, Obstacles And The Explanatory Register

In the following table, we gather the types of time referred to by teachers and students as well as the explanatory register in which they work. As students or teachers work in various explanatory registers, answers which contain more than one conception are classified in one or more frames. We summarize in table 9 our statistic result.

Table 9

Types of times and explanatory register

	Students' explanatory register		**Teachers' explanatory register**		**The same explanatory register (students and teachers)**		
	sample: 47		sample: 58			teachers	students
Sagittal time	Determinism	40 %	Finalism	3 %	Anthropocentrism	34 %	76 %
	Finalism	23 %	Creationism	12 %			
	Mythic	2 %	Brutality	3 %	Negative thought	5 %	19 %
	sismology	31 %					
	Naturalism	25 %			Environmental (short time)	4 %	29 %
	artificial	8 %					
	Psychologic	8 %			Catastrophism	36 %	68 %
Deep time	Gradualism	29%	Environmental (long time)	36 %	Evolutionism	68 %	31 %
	Positive thought (recycling)	2 %			Geomorphology	22 %	6 %
					Tectonic	31 %	11 %

The majority of teachers and students, when they link time with life, earthquakes, or other living concepts, mention concepts which refer to the conditions of human life. For 40% of students the fate of humans is predetermined by divine creation. Life, which is a creation of God, converges to an end. This teleology is directly related to recurrent anthropomorphism in responses (76%) but also among teachers (34%), itself related to life expectancy. The use of time is a function of the explanatory register in which each student works. Diversity due mainly to the explanation of biological or geological processes of a given phenomenon shows the difficulty of deciding on the slowness or the brutality of these phenomena.

Generally, the seismic activity is explained by the students (31%) as a snapshot tectonic phenomenon whose duration does not exceed a few seconds. The other part of explanation is reduced to catastrophism (36% of teachers and 68% of students). They tend to consider the consequences of this phenomenon -the earthquake- as an event seen in terms of brutality, human life; destruction, threat and death. Many students think that any loss is negative, which induces them to think negatively about the consequences of the earthquake but also about other phenomena, like biological crises. Some teachers (3%) consider an abrupt extinction as an event that requires a relatively short time and involves conceptions that refer to catastrophism. However, students (29%) consider that the biological crises are gradual and take place over a relatively long period of time.

The explanation of the two phenomena (earthquakes and biological crisis), oscillates between the two types of time, induces a negative thought clearly expressed in some answers (5% of teachers and 19% of students). We especially identified both obstacles linking cognitive psychology and myth. In most cases, students explain the phenomena in a short time framework not exceeding days, years or eras. It seems that this is a psychological obstacle of the time immensity perception. Some students speak about the notion of "break" probably related to a story, summarized until recently as the earthquake that has developed a mythical obstacle; "*During an earthquake, the earth opens and swallows human beings*". Sensitive knowledge is also an obstacle to investigate scientific knowledge, in some answers.

The geometric shape of the mountains let students develop an artificial conception (8%) of their training while the geographical space and greenery let them work in a natural framework (25%). This artificial conception finds its origin in the patterns of house construction, elements of earth that invade the green spaces. In both explanatory registers, students but also some teachers use a short time related directly with daily life, and consequently with anthropomorphism. Understanding geological or biological processes limits (8%) managing the immensity of time, in fact, students do not exceed a few eras and centuries when they explain biological crisis or formation of mountain. students try to turn biological crises into a recent phenomenon.

Some environmental problems are applied by teachers and students respectively to deep time and sagittal time. For teachers (36%), recycling and climate change require a very long time which is measured in millions of years. For students (29%), geochemical reactions (dissolution of limestone) or the melting of snow, take a few days. We note that the students refer to short periods when it is a limited environmental event, so that students work in a more comprehensive explanatory register that takes into account the time needed to recycle plastic material, for example.

Any loss, destruction, crisis related to earthquakes, tsunamis or biological crises develops among students (19%) and teachers (5%) negative thinking which often refers to a sagittal time. In contrast, geomorphology and environmental problems such as plastic recycling, for some students (2%), require a very long time. 22% of teachers and 6% of students explain the earth changes in a tectonic register which involves a slow time in millions of years. The mountain ranges require millions of years to form a green space according to some students.

When students work in a tectonic explanatory framework (31%), evolutionary (68%) or related to geomorphology (22%), they mention a relatively deep time because the process of a geological phenomenon takes place over millions of years. However when working on biological crises, teachers lean toward brutality because for them it is an event. Students consider biological crises as gradual phenomena (gradualism) which reflect the slow disappearance of a species (29%). Noting that students consider the biological crisis a slow process due to disasters, while teachers consider it an event caused mainly by meteorites. The sudden appearance of living beings after a crisis is almost impossible for students while teachers talk about the possibility of this occurrence since a crisis promotes the release of ecological kennel.

Discussion

Linking time with natural phenomena (earthquakes, tsunami, convergence, subduction, collision, formation of mountain) and scientific concepts (life, geological scale, dating), related to biology and geology, shows that teachers and students work in various and different explanatory frameworks. From a methodological point of view, we have classified the answers at least in an explanatory register based on the time referred to and which varies mainly between two types: a relatively short sagittal time and a deep time counting millions of years. The categorization of responses is not automatic; the arguments put forward are analyzed carefully to identify obstacles when sample is referring to time or working in a given explanatory register, although obviously re-built.

Without claiming to be an exhaustive investigation on the types of time mobilized by students and their explanatory registers, we tried to summarize the epistemological obstacles to using time in explanations of problems that cover a multiplicity of time scales. It follows on from that:

Anthropocentrism seems to be an obstacle due to the overvaluation of human life and its explanatory register dominates almost all explanatory frameworks (determinism, catastrophism, creationism and creationism) that refer to the sagittal time. A significant number of students work, for example, in an explanatory register linked directly or indirectly to human, while we consider that narcissism limits the type of time mentioned to explain an event or a phenomenon.

The spectacular catastrophism is a media-generated obstacle highlighting the spectacular aspects of an event or a phenomenon (earthquake or biological crisis). Every human extinction, equipment or geological (subduction or collision) is negative. Students and teachers develop more emotional and mythical patterns that may refer to a psyche of objective thought fascinated by any symbol of destruction. A deeper relationship between assertion and apodicticity would identify unconscious knowledge the basis of scientific knowledge.

Students tend to consider a biological crisis as a phenomenon in which the disappearance of species is gradual whereas teachers consider it as a brutal event. But if the mass extinction is brutal, it requires a brief phenomenon that spans millions of years and if it is gradual it should start much earlier and eventually get rid of a large number of species. This coupling of phenomenon-event and brutalism-gradualism allows the reconstruction of two explanatory registers: the teachers' register based on deep time and the students' register based on sagittal time.

Slow geological or biological process allows students to work in a tectonic or evolutionary explanatory register that requires a very long time. When teachers explain earthquakes they tend to mention events and refer to a sagittal time. They also use the account to show the full impact of destructive earthquakes. When it concerns environmental education, it is rather teachers are v rather likely to mention a short time. Naturalism, in turn, promotes the use of a short time by students, while teachers use a long time when working in a geomorphologic register.

It should be reminded that our sample, mostly students tend to restrict deep time to a calendar scale and historical problems to functionalist problems while researchers transpose the actual time to an imagined past to exceed the abstract level of time, difficult to conceptualize. Some students use stories to build the historicity of geological or biological problems. Other students work in an explanatory framework of an event, probably produced by anthropocentrism which limits the reconstruction of the possible history of natural phenomena according to time. Already, to manage the incommensurability of time, the students built a constructivist approach or a "*personal metaphor*" based on his own criteria. However, if students work in complementary explanatory frameworks to take into account the sagittal time and the deep time, cyclical time is almost absent from their explanations. It seems useful to work again on this concept which requires a heuristic investigation. It is also interesting to continue the study of the elements of the explanatory register in their assertoric and apodictic range.

The definition of geology, and partly that of biology, cannot be restricted, unnecessarily, to the universalism of physical sciences. *In contrast to the physical sciences, which tend to be predictive, experimental and reductionist in nature, geology is historical, descriptive, and systems oriented* (Dodick & Orion, 2003b). Educationally, linking biology and geology in an interdisciplinary approach allows students and teachers to build explanatory frameworks, beyond the paradigm of experimental science in which they refer to temporal connections affecting comprehension, outside geology, or other areas (history, astronomy and ecology). The revolution of "deep time," specify the main role of geology in the building of an imagined past of our planet, and therefore does it not submerge disciplinary boundaries to accelerate the failure of mono-disciplinary framework?

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TABLE 10

Examples of teachers' responses for each relationship

Relationship		Responses
Time	life	*"Life begins with birth and ends with death, life is a period of time, it progresses over time"*
	earth	*"The earth is a set of geological phenomena that occur during periods more or less slow"*
	alive	*"Life and earth are the two mechanisms by which living beings change over time"*
	geological scale	*"Using geological scale we can determine the precise time of a geological phenomenon, expressed in millions of years"*
Earthquake	life	*"These are natural accidents as a result of the destruction of ecosystems within the biosphere; natural disasters can devastate ecosystems that support life"*
	earth	*"geological mechanism, the two phenomena are mainly due to the movement of tectonic plates"*
	living beings	*"Indeed, we may assume the term disaster on two phenomena that allow the extinction of living beings"*
	geological scale	*"Earthquakes and tsunamis occur instantly several times in a short time"*
Dating	life	*"It allows the determination of the exact time of life; absolute dating by radioisotopes used to date the origin of life and its appearance"*
	earth	*"The dating of the earth and the study of fossils to determine the age of the strata"*
	living beings	*"The absolute or relative dating used to assess the age of living beings"*
	geological scale	*"The geological scale is constructed using age dating of fossils and stratigraphic"*
Convergence	life	*"The convergence and life are independent but the consequences of the first can affect the second"*
	earth	*"Morphology of the earth affects the topography of the land; construction of continents; determines the appearance of the earth; turns and changes"*
	living beings	*"The two phenomena (subduction and collision) cause changes in spatial localization of living beings (for example, you can find the same fossils in Africa and South America)"*
	geological scale	*"Convergence is a phenomenon that takes place at extremely slow time scales"*
Coupling geology biology	life	*"Life is threatened as a result of heating and gas. However, biogeochemical cycles maintain the recycling of minerals and organic elements necessary for life"*
	earth	*Firstly coupling touches the earth since it is formed of layers composed of minerals. These are the result of interactions of biogeochemical cycles"*
	living-beings	*"Living beings are essential parts in maintaining cycles of organic and inorganic matter recycling"*
	geological scale	*"Anyway, biological or geological events are dated with the geological scale, such as biological crises. These events can influence the lives of living beings evolving"*

Table 11

Examples of students' responses for each relationship

Relationship		Responses
Earthquake tsunami	living	"*Water removes the vegetation and the earthquake destroys homes causing more damage*"
	earth	"*The earthquake is an accident of the earth causing breakage and folding layers*"
	geological scale	"*The earthquake can be very fast and it can shake again three hours later*"
Formation of mountain	living	"*The mountain range enriched nature by green spaces and provides us with wood needed for life*"
	earth	"*The formation of the mountain is accompanied by anticlines and synclines*"
	geological scale	"The *formation of mountains took place a few centuries ago and gave rise to high-altitude reliefs*"
Biological crisis	life	" *animals disappeared after a natural disaster caused by a volcanic explosion*"
	earth	*The extinction of the dinosaurs occurred because of the separation of the continents by fault.*"
	scale	"*Herbivorous dinosaurs change places, many of them have disappeared and gradually carnivores ate them*"
Time	earthquake	"*After a seismic event, breaking rocks in place very quickly*"
	formation of mountain	"*Mountains were formed many years ago*"
	biological crisis	"*I think the biological crisis slows down the evolution of species because there is a loss of species in a century*"
Time	living	*The disappearance of living beings is linked to the disappearance of vegetation cover in a few decades*"
	earth	"*Faults trigger earthquakes for a few seconds and change the land, for example the island of Sumatra*"
	scale	"*Large animals such as mammoths lived for centuries in the ice after they disappeared because there is no food left*"