Cognitive Factors Affecting Student Understanding of Geologic Time

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Abstract

In the history of geology there have been two discoveries, plate tectonics and geological time, which have literally defined the way geologists view the earth. By geological time we mean the understanding that the universe has existed for countless millennia, such that man's earthly dominion is confined to the last milliseconds of the metaphorical geological clock.

The influence of geological time is felt in a variety of scientific disciplines including geology, cosmology, and evolutionary biology. Thus, any scientist or student that wants to master any of these subjects must have a good understanding of geological time.

Despite, the critical importance of geological time to such subject material, there has been very little attention given to it by science education researchers. This work addresses this gap in research.

In this study, geological time can be broken down into two different concepts :

1. A (passive) temporal framework in which large scale geological events occur. It is suggested that this understanding is dependent on the connections built between events and time. In the cognitive literature this is comparable to Friedman's (1982) associative networks, a system of temporal processing which is used for storing information on points in time. By this reasoning, this understanding of geological time should be mitigated by a person's knowledge of such events.
2. An (active) logical understanding of geological time used to reconstruct past environments and organisms based on a series of scientific principles. Based on this definition, it might seem that students unfamiliar with geology might be unable to reconstruct a depositional system; however, in structure, geo-logic is comparable to Montagnero's (1992; 1996) model of "diachronic thinking". Montagnero (1996) defines "diachronic thinking" as the capacity to represent transformations over

time; such thinking is activated for example when a child attempts to reconstruct the growth (and decay) cycle of a tree.

Montagenro (1996) argues that there are four schemes, which are activated when one attempts to reconstruct transformational sequences. In this study, three have been translated to the logical skills needed to solve temporal problems involving geological strata:

1. **Transformation:** This scheme defines a principle of change, whether qualitative or quantitative. In geology it is understood through the principle of actualism (i.e. "the present as key to the past")
2. **Temporal Organization:** This scheme defines the sequential order of stages in a transformational process. In geology, principles based on the three dimensional relationship amongst strata (ex: superposition) are used to determining temporal organization.
3. **Interstage Linkage:** The connections between the successive stages of transformational phenomena. In geology such stages are reconstructed via the combination of actualism and causal reasoning.

For the purposes of this research, a specialized (validated) instrument was designed, the GeoTAT which consisted of a series of open puzzles which tested the subjects understanding of the diachronic schemes as applied to geological settings.

In addition, two other questionnaires were distributed to sub-units of this population to answer questions that arose through the use of the GeoTAT: (a) a Time-Spatial test, which tested the possibility that spatial thinking, influences temporal thinking. (b) a Stratigraphic factors test which tested the influence of (geological strata) dimensions on students temporal awareness. In addition, qualitative research was pursued in the classroom and field by studying and interviewing students who were studying geology and palaeontology as part of their matriculation studies.

As a result of this study it was possible to construct a model of temporal thinking which permits a subject to reconstruct geological features in time. Based on this model, it was possible to outline the factors which affect a subject’s ability in “reconstructive” thinking:

a. The transformation scheme which influences the other two diachronic schemes.
b. Knowledge, most importantly empirical knowledge (such as the relationship between environment and rock type) and organizational knowledge (i.e. dimensional change).

c. Extra-cognitive factors such as spatial-visual ability which influence how a subject temporally organizes 3-dimensional structures such as geological strata.

Amongst the non-geology majors, it was seen that there was a significant difference between samples composed respectively of the high school and grade 9 students and grade 7 students in their ability to understand geological phenomena using diachronic thinking. This suggests that somewhere between grades 7-8 it is possible to start teaching some of the logical principles permitting one to reconstruct geological structures. These include: complex superposition (consisting of tilted strata), correlation (two outcrop problems), and the basic principles of diachronic thinking.

Moreover, this research shows that the ability to think diachronically can be improved if exposed to the earth sciences. A comparison of high school (grade 11-12) geology and non-geology majors indicated that the former group held a significant advantage over the later in solving problems involving “diachronic thinking”. This relationship was especially strengthened by the second year of geological study (grade 12), with the key factor in this improvement (probably) being exposure to fieldwork. Fieldwork both improved the students’ ability in understanding the 3-dimensional factors influencing temporal organization, as well as providing them with experience in learning about the types of evidence that are critical in reconstructing a transformational sequence.