Mastering the Concept of Geologic Time: Novice Students' Understanding of the Principles of Relative Age

Michelle A. Speta, Leslie F. Reid
Department of Geoscience, University of Calgary
maspeta@ucalgary.ca, lfreid@ucalgary.ca abstract # ED13A-0608

UNIVERSITY OF CALGARY

ABSTRACT

Misconceptions can adversely affect students' mastery of the fundamental geoscience concepts necessary for development of the knowledge base required to become a professional geoscientist. In the fall of 2009, in-class learning assessments were introduced into a large (400 student) undergraduate introductory geoscience course to help students develop expert-like, problem-solving skills for geologic problems. They were also designed to reveal students' misconceptions on geoscience concepts in order to help direct the course of instruction. These assessments were based on simple, real-world scenarios that geoscientists encounter in their research.

One of these assessments focused on the concept of geologic time. It asked students to give the relative ages of granite, schist and shale based on a sketch of two outcrops, and to describe the reasoning behind their answer. In order to test all of the principles of relative age, the assignment had two possible solutions. A post-course analysis of student responses on these assessments was carried out using a modified constant comparative analysis method to identify common misconceptions.

This analysis revealed that 61% of students failed to identify both possible solutions. Furthermore, 55% of students did not understand the principle of superposition and/or applied it to intrusive igneous and metamorphic rocks. 18% treated the once connected outcrops as having separate geologic histories. These results suggest that when to apply the principle of superposition, and how to apply the principle of original continuity were the aspects of relative geologic time with which the students had the greatest difficulty. Students also had difficulty using the principles of relative age to provide appropriate scientific reasoning for their choices.

Changes were made to the learning assessments for the fall 2010 semester based on the results of this analysis.

PURPOSE OF STUDY

Teaching novice geologists expert-like, problem-solving skills is a desired objective or learning outcome of introductory geoscience courses. However, these skills are rarely explicitly taught. A study by McConnell et al. (2005) found that half of the students entering these courses at the university level do not have the skills to understand abstract scientific concepts.

According to McConnell, examples of expert level, or abstract operational, problem-solving skills include:

- Supporting ideas with appropriate reasoning
- Thinking in "shades of grey," rather than "black and white" absolutes
- Looking for more than one solution to a problem
- Making predictions and logical inferences to solve unfamiliar problems

McConnell and colleagues also suggest that for students to learn science successfully, their understanding must be challenged in order to reveal misconceptions which, if undisputed, result in inaccurate mental models and a failure to attain a thorough grasp of fundamental concepts. The purpose of this study was to create an instructional tool to help novice geologists develop these expert-like thinking skills by revealing their misconceptions on basic geoscience concepts.

According to the Earth Science Literacy Initiative (2010), one of the fundamental concepts that need to be understood by science literate individuals includes geologic time.

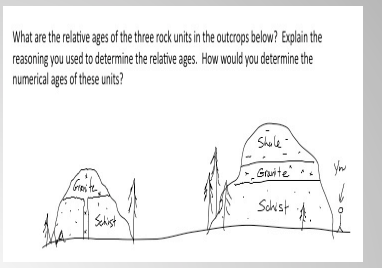

Figure 1: 2009 Learning Assessment

ANALYSIS METHOD

We used a modification of the constant comparative analysis method described by Hewitt-Taylor (2001) (as shown in the schematic cycle in Figure 2).

Two rounds of reading through the entire data set were necessary to ensure that all misconceptions were identified.

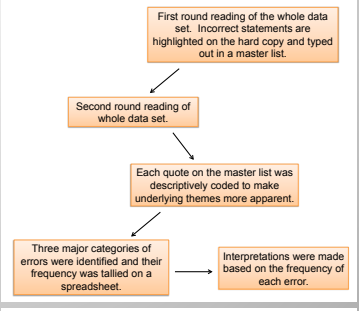

Figure 2: Schematic diagram depicting the modified constant comparative analysis method used in this study.

RESULTS

We found the three most common errors made by students on the learning assessment were:

1. Failing to identify both possible solutions
2. Misunderstanding the principle of superposition
3. Missing the principle of original continuity

The analysis also revealed that many of the errors made in the proposed geologic history of the outcrops reflected a weak understanding of how each of these rock types formed

The frequency of each misconception is shown in Figure 3. Student quotes demonstrating these misconceptions are shown in Table 1.

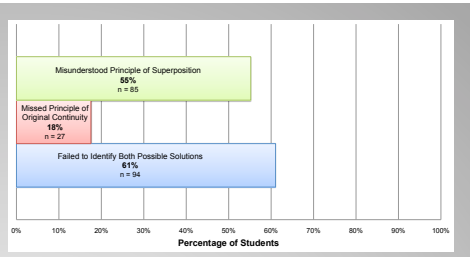

Figure 3: Misconception Frequency Histogram (n_{total} = 154)

Table 1: Student Quotes Demonstrating Misconceptions

Uniformitarianism	*"By using the principle of uniformitarianism, geologists emphasized that physical processes do not occur at exactly the same rate through time, which means that schist, granite and shale didn't occur at the same period of time."*
Superposition	*"The principle of superposition states that sediment layers on the bottom are older than the sediment layers on top. This shows that schist is relatively older than granite, which is relatively older than shale."* *"The principle of superposition could be applied to the granite (igneous) and shale (sedimentary) layers making the shale younger than the granite."* *"This is the law of superposition where schist needs high temperatuer [sic] and pressure."* *"The shale would be the youngest because of super position stating sedementary [sic] rock is youngest."*
Original Horizontality	*"According to the principle of original horizontality schist is the older then granite then shale [sic]."* *"From looking at superposition, we would say shale is the youngest, but because of original horizontality, granite could be younger than shale."*
Original Continuity	*"The shale has to be the youngest layer because of the fact that it only formed on outcrop B. This must mean that it formed on outcrop B after the errosion [sic] occurred and seperated [sic] the two outcrops, therefore not letting the layer spread to outcrop A."*
Rock Cycle and Relative Age	*"...the granite intruded in between 100% shale country rock and provided enough of a pressure change to metamorphose the shale below the sill into schist. In this case the schist would have been the most recent form regardless of its cross-cutting relationship with the intrusive granite."*

Table 2: 2010 Learning Assessment Changes

Issues with 2009 Assessment	Changes to 2010 Assessment
More than half of the students did not support their proposed geologic history with appropriate reasoning	Detailed instructions on how to present reasoning (e.g. discussing the processes that formed the rock, explaining the applicable principle of relative age, describing the nature of the contact between the units)
More than two thirds of the students failed to identify both possible solutions	Indicate that there is two possible solutions in the instructions
Students had the greatest difficulty with principles of superposition and original continuity	More explicit instructions and the addition of a contact metamorphic lithology to encourage students to think about how each rock formed
Post-course student feedback revealed that students wanted a follow-up review of the assessment to discuss errors	Dedication of one class to a follow-up discussion for each learning assessment to go over common misconceptions

Preliminary results from the 2010 learning assessments indicate that the principle of superposition continues to be an issue for students, however a comprehensive analysis will not be completed until the semester ends.

Using the diagram in the handout, explain the geologic history from the oldest to youngest event for the four different rock units in the outcrops. There are two possible solutions. Use the tables provided below for your answer and be sure to include the following:

- the reasoning for your order of events (i.e. the geologic processes of rock formation and/or the principles of relative geologic time)
- the nature of the contacts between the units if appropriate (i.e. conformable, unconformable, faulted)

Ss = sandstone, Gn = gneiss (the squiggly lines in the gneiss layer indicate the orientation of the gneissic foliation).

Hints: Thrust faults can follow geologic contacts. Gneiss is a high-grade metamorphic rock from regional metamorphism, hornfels is a contact metamorphic rock.

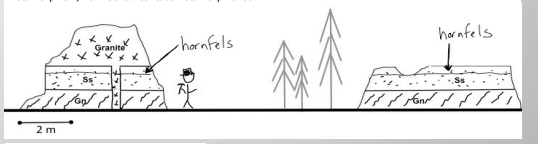

Figure 4: 2010 Learning Assessment

REFERENCES

McConnell, D.A., Steer, D.N., Owens, K.D., Knight, C.C., 2005. How students think: Implications for learning in introductory geoscience courses. *Journal of Geoscience Education*, v. 53, n. 4, pp. 462-470.

Hewitt-Taylor, J., 2001. Use of constant comparative analysis in qualitative research. *Nursing Standard*. v. 15, n. 42, pp. 39-42.

Earth Science Literacy Initiative, 2010. *Earth Science Literacy Principles Guide*. Obtained from: http://www.earthscienceliteracy.org on Dec.1, 2010.

ACKNOWLEDGEMENTS

We thank Dr. Dave Eaton from the University of Calgary for sponsoring the submission of this poster. Funding for this project was provided by the Tamaratt Teaching Professorship.