Understanding Geological Time:
A Proposed Assessment Mechanism for Beginner and Advanced Geology Students at The University of British Columbia (Vancouver)

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Abstract

Having a firm grasp of geological time is essential to developing a full understanding of the Earth. Many studies have focused on students in the K-12 and entry-level college education systems. The proposed 20 question, mainly multiple-choice, assessment mechanism is designed to probe the understanding of geological time amongst beginner (entry-level college) and advanced (graduating) students in a major's geology program. A four step process involving: establishing instructor expectations of students, development of an assessment mechanism from existing resources, think-aloud validation with student volunteers, and an iterative refinement process for the developed assessment mechanism revealed insights on student behaviour and creating multiple-choice tests. Student behaviour is assessed via displayed reasoning acts of recalling facts, posing questions, making evaluations, and pausing. From validation interviews students displayed gaps in their understanding of geoscience terminology and a lack of technical vocabulary when reasoning questions out-loud. The refinement process has revealed the following problems associated with developing multiple-choice questions: unclear wording, emphasis of key words, easily eliminated distractors, limitations on cognitive levels of assessment, use of pre-validated questions outside of their context, and testing multiple concepts in one question. The implementation of this assessment should aid in development of the geology curriculum within the Department of Earth and Ocean Sciences at UBC by giving instructors a snapshot of student understanding of geological time. This study serves as a springboard for further scholarly investigations of geology education at UBC.

Introduction

Geological time is a fundamental concept in building a basic understanding of the Earth (Zen, 2001) and is fundamental to a students' mastery of the geosciences (Dodick and Orion, 2003a). Previous work on the subject has focused within the domains of K-12 education and lower level college (Trend, 1998; Dodick and Orion, 2003b; Libarkin et al., 2005; Libarkin and Anderson, 2005).

This study looks at instructor expectations of both beginner (after 2nd year in the program) and advanced (graduating) geology students, and how well students understand these concepts related to geological time. With an internal department review of the UBC geology curriculum underway since 2008, now is a good time to evaluate student capabilities. Hopefully this work may lead to development of curriculum that works to enhance student performance in appropriate ways. Focusing on beginner and advanced students sets it apart from other efforts and provides an opening for new directions of geoscience education research within the UBC context.

Methodology:

The development of this study can be summarized into four steps (Figure 1) which lead to the creation of the final assessment mechanism. Instructor expectations of students were established via interviews (Table 1), the results of which became the basis for making the first draft of the testing mechanism. Not all concepts outlined by instructors were included (Table 1) due to difficulties creating multiple choice questions that sufficiently tested those concepts.

Think-aloud validations were conducted with students to ensure that proposed assessment questions were interpreted correctly. This method is also a way to supplement the inherent weakness of multiple-choice tests to tease apart critical thinking processes (Norris, 1990). Validation and refinement were iterative steps that produced the final assessment mechanism (Figure 2).

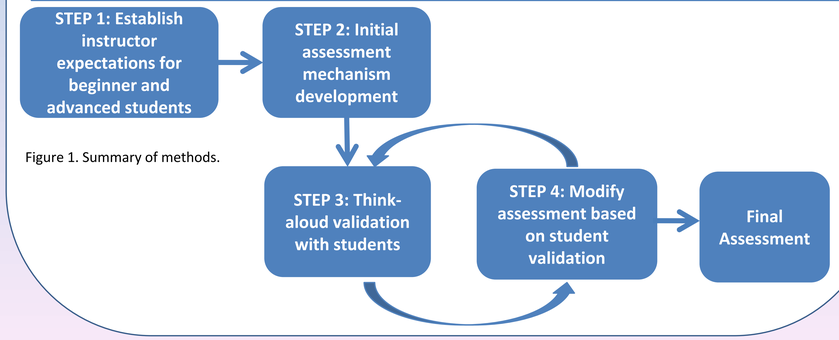

Figure 1. Summary of methods.

Table 1. Key concepts and expectations of beginner and advanced students. Italicized font indicates concepts that were not specifically addressed in the final assessment mechanism.

Key Concepts	After 2nd year in program (Beginner)	Before Graduation (Advanced)
Timescale	▪ Understand the immensity of geological time ▪ Familiarity with terminology of geological eons, eras, and periods	▪ Reproduce time scale to eras, periods, and epochs with the associated dates ▪ Explain framework for its construction – that it was based upon succession of fossil types
Relative Dating	▪ Apply knowledge of stratigraphic principles and sedimentary features to create a geological history ▪ Know that fossils can be used to define units because they are separated in time (life changes through time, therefore remains of life can be used to distinguish different periods of time)	▪ Apply relative dating principles to field and map interpretations to create geological histories
Absolute Dating	▪ Recognize commonly used radiometric dating methods ▪ Define the principles of radioactive decay	▪ Explain basic principles of multiple dating processes ▪ Apply multiple dating processes appropriately in different geological settings ▪ *Calculation of ages from data*
Earth History	▪ Describe the history of Earth's formation ▪ Know the relative timing of major geologic events ▪ *Describe plate tectonic theory*	▪ Describe the paleo-geographical development of Earth (influence of tectonic plate movement) ▪ *Reconstruction of Earth history from evidence found in the rock record* ▪ Placement of major geological events on the timescale (extinctions, formations, plate movements etc…) with associated dates
Uniformitarianism	▪ Know the concept and understand the context (technological limitations) in which it was created	▪ *Point to examples of the antiquated nature of the concept*
Rates and processes	▪ *Knowledge of timescales of basic geologic processes (mountain building, volcanism, lava cooling, metamorphic events)*	▪ Quantify geological processes from chemical and physical rate laws

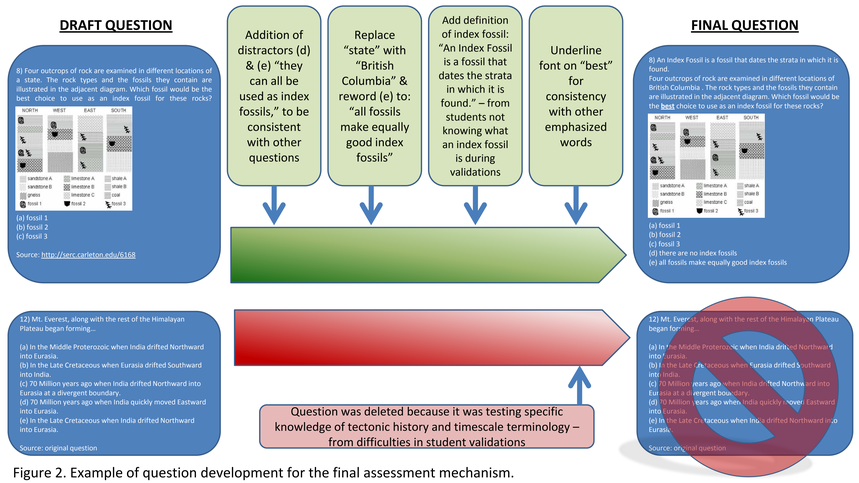

Figure 2. Example of question development for the final assessment mechanism.

Results:

The product of this study is a twenty-question assessment that addresses most of the key concepts identified by faculty members. The validation process revealed a number of expected reasoning acts (Norris, 1990) plus unexpected observations of student behaviour (Table 2). Validation also made several areas of weakness apparent in the questions that were being asked (Table 3).

Table 2. Expected (Norris, 1990) and unexpected observations in student behaviour.

Expected observations from Norris (1990)	
Reasoning Act	**Behaviour**
1) Citing factual details	Recalling a factual detail given in an item prior to the one currently being done, recalling such a prior detail incorrectly, or stating a detail in the current item
2) Self-questioning	Posing questions that appear to be directed to the subject rather than to the interviewer
3) Making evaluations	Either evaluating previously stated judgments or conclusions, or evaluating ones that had not been verbalized
4) Pausing	Either making verbal inflections (Ohhh! Mmmm!), or being silent.
Unexpected observations from this study	
Observation	**Description**
5) Lack of descriptive vocabulary	Student thought process uses lay terms to describe units, relationships, or specific items ("Thingy", "Between these other things")
6) Terminology gaps	Lack of knowledge of simple geosciences terms (geological history, index fossil, accretion)

Table 3. Descriptions of common weaknesses in questions.

Common weakness	Description
1) Unclear wording	Questions were worded awkwardly or did not focus on a specific outcome required by the student
2) Testing multiple concepts	Questions were testing the understanding of more than one concept (Knowledge of order and specific dates on the time scale)
3) Key-word emphasis	Words that were important in the correct interpretation of a question were not highlighted ("best", "not", "primarily")
4) Inappropriate distractors	Distractors that could be eliminated too easily or were not clear when interpreted by students
5) False positives	Questions that allow for the correct answer to be reached by incorrect reasoning

Discussion:

The reasoning acts (Table 2) that were observed during validation interviews reveal some insights on how students think:

- Students tend to try to recall facts instead of working through problems with information that is provided
- They will rephrase questions to themselves if the answer is not apparent
- Students would often select answers that they felt 'sounded' correct as opposed to ones that they knew were correct
- Silence leaves thought processes inaccessible to the interviewer but often followed the act of self-questioning
- Gaps in student understanding of terminology reveals that many exam questions may, in fact, be testing vocabulary instead of understanding of a particular concept

The multiple choice questions that were used throughout the validation process were refined in a few recurring ways (Table 3). These reveal important take-home messages for creating multiple choice tests:

- Clear wording provides the best chance at testing intended subject matter
- Key-words should be emphasized to allow students to focus in on what question is being asked of them
- Using previously validated test questions outside of their context may provide inappropriate distractors for the intended test audience
- Questions that test multiple concepts (Figure 2) do not indicate which portion of the distractor students do not know

Conclusions:

This is an initial step in creating a scholarly approach to assessing student understanding of geological time within the Department of Earth and Ocean Sciences at UBC. The four step process outlined (Figure 1) has revealed several expected student behaviours (Table 2) with implications for instructors and areas of improvement for multiple choice questions (Table 3). Subsequent steps will need to involve the implementation of the proposed assessment, as well as the continued development of the test items through validation. I look forward to seeing what studies and changes in the department come out of this work.

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