Measuring student gains in

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Abstract

The Earth and Ocean Sciences Department (EOS) at the University of British Columbia (UBC) is optimizing, redesigning, and assessing courses as part of the Carl Wieman Science Education Initiative (CWSEI). The introductory Geoscience lab (EOSC 111: A Laboratory Exploration of Planet Earth) was one of the first courses to begin optimization under CWSEI. This unique course draws together many aspects of Earth and Ocean Sciences and serves as the common lab course for four quite different first year courses, available to students from any faculty.

We will outline particular steps in the optimization process of this course:
The development and use of explicit lecture and lab level learning goals, to make what is required and what is assessed transparent to the students.
A variety of techniques and pedagogy used in this course including: individual and group quizzes, invention exercises, use of the geologic museum (the Pacific Museum of the Earth), rotating Teaching Assistants with different expertise, and explicit use of the Scientific Method
Evaluation of student learning gains through the use of pre- and post-lab assessments directly related to learning goals. These assessments are administered on the first day of class and after the completion of each lab. Preliminary analyses of these assessments are presented.

Results of the first full semester of assessment show some variety within the course. Variation in learning gains can be ascribed to many causes such as: lab activity quality, student prior knowledge, specificity of learning goals, and assessment question quality. Data related to these and other causes will be discussed.

Learning Goals

Use of learning goals in an academic context is an important step to clearly define what is expected of the students. Clear goals allow students to know what is expected of them. We have defined both course level and lab level goals.

Course Goals For EOSC 111
•Make interpretations and draw conclusions based on observations and evidence in an Earth system science context
•Apply qualitative and quantitative approaches to Earth system data and samples
•Appreciate that Earth systems science is exciting and relevant to society and our lives
•Recognize the interconnectedness of Earth system science

Sample Lab Goals – Earthquakes
•Demonstrate the conditions under which different buildings are most likely to be damaged in an earthquake.
•Approximate the location of a historic British Columbia earthquake using data from three seismographs
•Compare locations in the Metro Vancouver region based on their likelihood of damage in an earthquake

Invention Activities in Labs

Incorporating "invention" activities into labs (Schwartz and Martin, 2004)
Previous, definition activity: *Brainstorm a definition for "mineral".*
New, invention activity: *Which of these objects (Figure 1) are minerals and which are not? Explain your reasoning.*

Pre-Post Assessment Results:
Before the invention activity, 17% of students answered the following question correctly.

Which of the following groups only contains minerals?
A. *Ice, water, quartz*
B. *Quartz, granite, steel*
C. *Quartz, water, iron pyrite (fool's gold)*
D. *Quartz, ice, iron pyrite (fool's gold)*
E. *Quartz, steel, iron pyrite (fool's gold)*

After the invention activity, 70% of students answered correctly (Figure 2).

Did the activity help students achieve the learning goal?
In a post-lab on-line survey, more students reported the invention activity As "very much help" or "much help" in achieving the learning goal, compared to fewer categorizing the definition activity as "very much help" or "much help" (Figure 3).
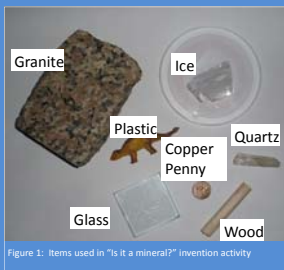

Figure 1: Items used in "Is it a mineral?" invention activity
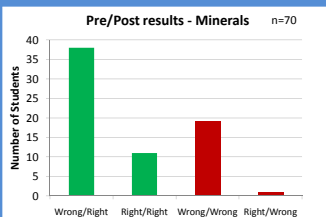

Figure 2: Pre-post assessment results. After completing the "Is it a mineral" activity, 70% of students answered the assessment question correctly.
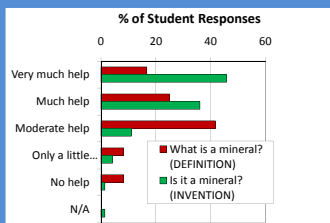

Figure 3: Student responses to "How well did [the lab activity] help you achieve [this goal]?" Learning goals evolved between terms. Stated goal for the "definition" activity was "Distinguish between a rock and a mineral in everyday life". Stated goal for the "invention" activity was "Make careful observations of the building blocks of the Earth's surface: rocks and minerals"

What have we learned for the future and for other labs?

•Incorporate meaningful invention activities where possible.
•Match invention activities to clear learning goals
•Keep iterating for clear pre-post assessment questions, tied to goals.

Group Quizzes

Using pre-lab quizzes as learning experiences
Because this lab course serves four different lectures courses, we ask students to prepare ahead of time. Students read several pages of background information before coming to lab. At the beginning of the lab period, students take a short quiz on the pre-readings, individually. Directly after the individual quiz, students re-take the quiz in small groups.

Based on research in team-based learning (Michaelsen et al 2002) and peer instruction (Mazur 1997) and group quizzes (Rao et al. 2002) we hypothesized that students would learn from discussing the quiz questions with their peers and explaining/defending their answers. But is this an effective learning experience? How could we tell?

Do groups score higher than the highest-scoring individual within the group? Not often. Mostly the groups matched the highest scoring individual student (Figure 4). This is possibly because many of individuals and Groups scored perfect results on the quizzes.

What decisions do the groups make? Mostly, they go with the correct majority. In just 2 cases (n=168), a group chose a correct answer when no individual in the group got it correct (Figure 5).

What have we learned for the future?

• Make the quiz questions conceptually challenging, such that most individuals score less than 100%, to better see effects of group discussion.
•Use results from previous terms and interviews with students to construct and rewrite questions.
• Strive to illuminate common misconceptions within the quiz questions
• Listen in on group discussions – gain information about how they operate
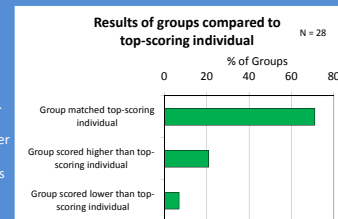• Interview students about the quiz structure (or conduct focus groups)

Figure 4: In more than 90% of cases, group scores matched or exceeded the best individual score in the group. Occasionally groups did better than the highest scoring individual. Only rarely did groups score lower.
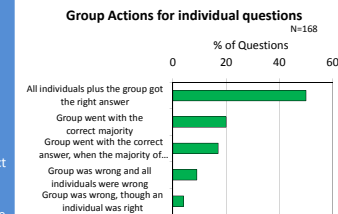

Figure 5: For half of the questions, all individuals and their group got the correct answer. In cases of disagreement, students primarily went with the correct majority. In cases where a minority of individuals are correct, those individuals appear to have been able to convince their groups more often than not.

Some other unique aspects of this course

Mineral Museum
Our department houses the Pacific Museum of the Earth and students have the opportunity to use the museum specimens in several labs (Figure 6). For more information on the museum visit:
http://www.eos.ubc.ca/resources/museum/index.html

Rotating Teaching Assistants
In this course Teaching Assistants do not work with one class the whole semester, instead graduate students work on labs in which they have expertise. Student and TA comments indicate they prefer this arrangement.

Explicit Use of the Scientific Method (Hannula 2003)
We have redesigned some labs in this course to make much more explicit use of the Scientific Method.

Figure 6: The Pacific Museum of the Earth is housed within Earth and Ocean Sciences at UBC. There are many excellent samples on display; including a wide variety of mineral, rock, and fossil specimens and a full sized Lambeosaurus skeleton. Many of these samples are incorporated into activities in EOSC 111.

an Introductory Geoscience Lab

Pre/Post Assessments

Once learning goals are defined, pre/post assessments can be targeted at these goals to assess whether and how well students have achieved the goals.

Procedure
• Students are given an assessment at the beginning of the term
• Students answer identical questions online within one week of completing each lab
• Individual pre/post responses are matched
• Students earn participation marks for completing the assessment

What it looks like when it doesn't work

The following questions show some situations where the assessment was not effective and what steps we have taken to remedy the situation.

Poor/No Relation to course goals

Question - What causes most of the waves in the ocean?
A) Tides   B) Earthquakes   C) Wind   D) Tsunami   E) Currents

Related Learning Goal – *none*

Though this is an useful and quite common question in Ocean Science, students in this lab did not perform better after completing our waves lab, as shown in Figure 8. This question is not relevant in our context because the origins of waves are not related to our learning goals or lab activities. Since it is not covered in our labs or our pre-readings, we have removed it from the assessment.

Misleading results

Figure 9: Diagram for Dinosaurs assessment question

Question - If the fossil foot prints shown in the diagram above (Figure 9) are evidence of a large (hungry) dinosaur chasing a smaller dinosaur, did the little dinosaur escape, or did it become lunch? Note that the stride lengths are equal.
a. It escaped   b. It became lunch.
Circle a or b and explain your reasoning.

Related Learning Goal - *Use measurements of fossils and comparison to modern creatures to estimate the weight, stride length, and speed of a dinosaur*

If we were only to look at the multiple choice part of this question, it would appear that the majority of students get it right or improve pre and post lab (Figure 10). However, when the explanation is considered the majority of students do not understand the concept after the labs (Figure 11). This question has now been rewritten as a multiple choice question (with six options) using student explanations as distractors. We will reevaluate its effectiveness after the results of this term; if the results still indicate a large number of students having difficulty with this concept we will reexamine the lab activities.

High Initial success. Too high.

Question - Which of the following samples (A, B, C, or D) is the most diverse?

Figure 12: Initial Diagram for Plankton assessment question

Explain your reasoning.

Related Learning goal - *Apply measures of biodiversity to compare samples of marine organisms in our local ocean*

The diagram above makes this question too simple to be a useful assessment. Most students got it right in both the pre and post assessments (Figure 13). If fact, the lab apparently confused more people than it helped (though these numbers are very small and are likely related to guesses). To correct this issue we created the more challenging diagram below to go with the same question (Figure 14). Results from this semester indicate that fewer people answered correctly in the pre-assessment; creating room for improvement after the lab (Figure 15).
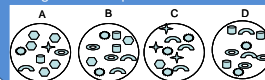
Figure 14: Revised Diagram for more challenging plankton assessment question

Developing Effective Pre/Post Assessment questions

• Identify learning goals
• Ask students to respond to open ended questions and explain their reasoning
• Use student responses to develop multiple choice distractors (C. Wieman, pers comm.)

Examples of student generated distractors

Each house depicted in this cross section (Figure 7) has a well. Which of these wells should produce the most water? Why?
a) House A – because clay and silt forms near a river
b) House A – because clay and silt contain more water than sand and gravel or granite
c) House A – because the clay and silt hold the water without letting it drain through
d) House B – because sand and gravel is the softest material
e) House B – because water flows easily in sand and gravel
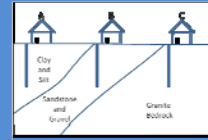f) House C – because water collects at the bedrock

Figure 7: Diagram for ground water assessment question.

What it looks like when it works

The following questions serve as examples of effective pre/post assessment questions related to the learning goals of this course

Activity, Goals, and Assessment Linked

Question - As waves approach shore, which of the following happens?
A) The waves speed up   B) The wave height decreases
C) The wave period decreases   D) The wavelength decreases
E) The wave frequency decreases

Related Learning Goal - *Devise methods to measure and compare wavelengths and periods of different wave trains approaching a beach*

This question shows high improvement on a difficult concept (Figure 16). It appears our lab activity is helping most students meet our expectations.

Continued Development of an Effective Question

Question - The lines on this map (Figure 17) represent water table elevations in metres. What direction does groundwater flow from the X?

a) Toward one of the letters (specify which letter)
   A B C D E F G H
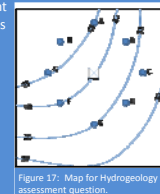b) Straight down into the ground
Explain your reasoning.

Related Learning goal - *Predict, measure, and explain how water flows through different geologic materials*

Figure 17: Map for Hydrogeology assessment question.

Students show high improvement on this question (Figure 18). In the latest version, we used the most popular choices to limit the number of distractors and make it exclusively a multiple choice question. This term a similar percentage of students chose the incorrect answers in the pre-assessment.
These assessment results reveal that a high proportion of students still do not understand the concept after the lab. This may be because they are having difficulty with contour maps or do not understand how groundwater gradients work. Based on this evidence we are incorporating more contour map activities into the course.

What have we learned from Pre/Post Assessments?

The pre/post assessments have helped us determine which parts of the labs are helping students achieve learning goals and which parts need to be redesigned. We will use this knowledge to guide our development on this course.

What's next for EOSC 111?

• Using data and evidence from assessment results iterate and test:
   a) pre/post assessment questions
   b) quiz questions
   c) labs, lab activities, and learning goals

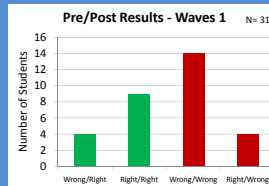• Share results with instructors in other contexts and at other institutions

Pre/Post Results - Waves 1
N= 31
Figure 8: Pre-post assessment results for Waves question. Almost 50% of the students did not improve after the lab.
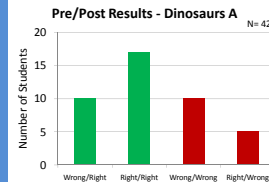
Pre/Post Results - Dinosaurs A
N= 42
Figure 10: Pre-post results for the first part of Dinosaurs assessment. A majority of students apparently performed well.
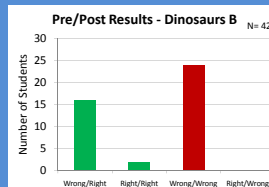
Pre/Post Results - Dinosaurs B
N= 42
Figure 11: Pre-post assessment results for the second part of the dinosaurs assessment. Though the majority of students got the part A correct, most of them could not explain why.
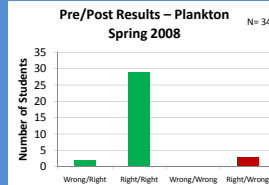
Pre/Post Results – Plankton Spring 2008
N= 34
Figure 13: Pre-post assessment results for plankton Spring 2008. This version of the question was to simple to be useful.
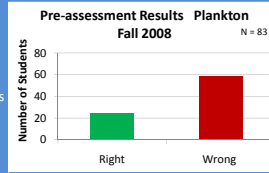
Pre-assessment Results   Plankton Fall 2008
N = 83
Figure 15: Pre assessment results for plankton Fall 2008. The redesigned diagram makes the question more challenging.
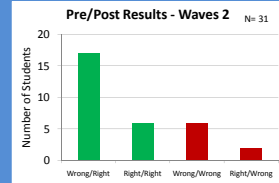
Pre/Post Results - Waves 2
N= 31
Figure 16: Pre-post assessment results for Waves. Students show a marked improvement after completing the lab activities.
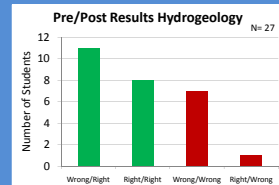
Pre/Post Results Hydrogeology
N= 27
Figure 18: Pre-post assessment results for Waves question. Almost 50% of the students did not improve after the lab.

References

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