

Engaging non-science students in large classes

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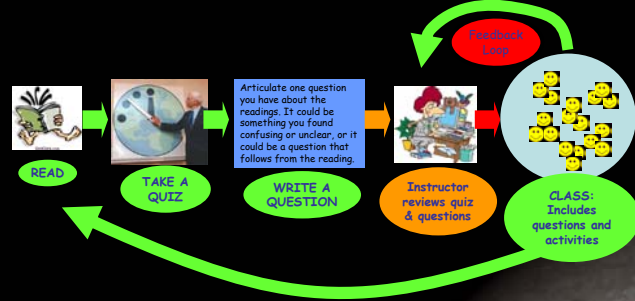


ABSTRACT

Most students in introductory geoscience courses are not headed toward careers as scientists. One high-enrollment science course may be a student's only opportunity to engage with science from a scientific perspective. Given that earth systems science is immensely relevant to human society today, engaging students in these large enrollment courses is a crucial and golden opportunity.

Two engagement techniques were used in a large class for non-science students called "Earth and the Solar System": (1) short on-line quizzes prior to each class, based on reading material (an aspect of Just-in-Time-Teaching), and (2) in-class activities that required students to address some important concept and submit a written response.

Although this was not a controlled experiment (students self-selected their participation levels), students who regularly kept up with the quizzes and regularly participated in in-class activities performed better on high stakes exams, even though all material was made available to all students for study. Surveys of students regarding the effectiveness of pre-class quizzes and in-class activities show that they regarded both as valuable learning experiences and favored keeping both aspects in the course.



WHEN STUDENTS PREPARE FOR CLASS THEY'RE MORE ENGAGED IN CLASS

HOW DO YOU GET STUDENTS TO PREPARE FOR CLASS?

It would be ludicrous to expect students to show up to a literature class having never cracked the book, yet in many introductory science courses, we expect our students to arrive completely unprepared. The "Just-in-Time-Teaching" model (JITT) changes those expectations (Novak et al., 1999) and the classroom dynamics.

HOW DOES JITT WORK?

- Students complete assigned reading before class
- Students complete a short, on-line, graded quiz due several hours before class starts
- The instructor reviews the quiz results and can modify what happens in class to address common, interesting, relevant questions

WHAT ARE THE BENEFITS OF JITT?

- Incentive for students to grapple with course material on an ongoing basis
- Students think about the material ahead of time and arrive with questions
- Students are engaged during class (in this case, 80 minutes)
- Basic material can be learned ahead of time, outside of class
- Class time can be spent practicing higher-level thinking skills
- Students get timely constructive feedback
- The instructor gets timely information about student thinking and misconceptions
- Students don't need to cram for exams, because they're studying regularly
- Everyone has much more fun

WHAT ARE THE QUIZZES LIKE?

Quizzes contain 5 multiple choice questions. Question 6 asks them to articulate a question they have about the reading.

EXAMPLES:

What is the evidence that the surfaces of Mercury, the Moon, and Mars are older than the surfaces of Earth and Venus?

- Older surfaces are covered with basaltic lava flows
- Radioactive dating of rock samples from each place
- Planets & moons with younger surfaces have magnetic fields
- The older surfaces have lots of visible craters
- The younger surfaces have visible volcanoes

Where is the eastern-most boundary of the Vancouver plate on which Vancouver is located? (First, of course, you'll need to figure out which plate we're on...)

- Just offshore of the eastern United States
- In the middle of the Atlantic Ocean
- Just offshore of Vancouver Island
- Just offshore of Newfoundland
- In the middle of the Pacific Ocean

Which of the following volcanic hazards would be easiest to run away from (assuming you were close enough to be in harm's way when the eruption started)?

- A lahar at Mt. Pinatubo
- A basaltic lava flow at Mauna Loa
- A pyroclastic flow at Mount St. Helens
- A caldera collapse at Yellowstone
- Volcanic bombs at Mt. St. Helens

ARE PRE-CLASS QUIZZES EFFECTIVE?

Students who attempted 20 or more quizzes scored about 7% higher on the high-stakes final exam than students who attempted fewer than 20 quizzes (Figure 1; p-value = 0.001). All quiz questions are made available to all students before exams.

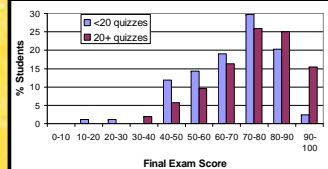


FIGURE 1: Histograms of final exam scores with students grouped by number of quizzes attempted of 23 possible (n=84 for <20 quizzes; n=104 for 20+ quizzes).

WHAT DO STUDENTS THINK?

On an end-of-term survey, students were asked three questions regarding the pre-class reading and quizzes. Students regarded the quizzes as helpful for learning (Figure 2) and challenging (Figure 3).

How much did the pre-class quizzes help your learning?

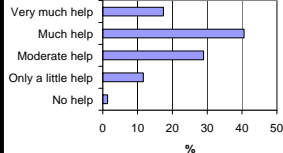


FIGURE 2: Students rate the pre-class quizzes generally highly, in terms of helping their learning (n=69).

How would you rate the pre-class quizzes in terms of challenge for you?

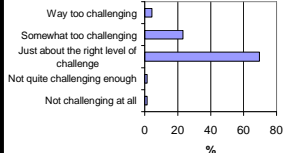


FIGURE 3: Students rate the quizzes on the "right" side of challenging. Only two students reported the quizzes were not challenging enough (n=69).

The third question was... "Any comments about the readings or the quizzes? Should they be kept? Expanded? Decreased?" Responses run 2:1 in favor of keeping the quizzes for every class. Nearly all "negative" comments simply suggested reducing the frequency to once per week.

Example student responses: "Keep the assessments! They are a brilliant idea. Makes studying for exams so much easier." "If it weren't for the quizzes I wouldn't have done the readings. PLEASE KEEP THE QUIZZES!" "Definitely keep them. They are a great study guide and a good way to keep students thinking about earth science outside of class."

"Students actually knew what they were talking about in class then" "I felt that the class quizzes were a valuable class tool in that they ensure that students keep up with the class material on a daily basis and don't fall behind. It is better to learn the material in increments as the course played, with pre-class quizzes rather than learning the material in overwhelming chunks. I felt the quizzes were very helpful in forcing students to read the material and applying what they learned, and that they should be kept as they are."

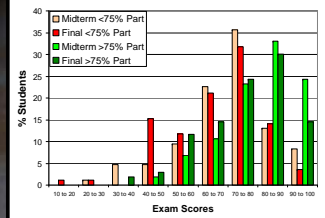


FIGURE 4: Histograms of midterm and final exam scores, comparing students who participated in in-class activities 75% of the time (n=85) for midterm (Final) to students who participated 75% of the time (n=103).

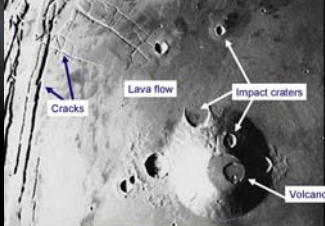


FIGURE 5: Which came first? Image of Uranus Tholus volcano and surrounding area on Mars (Viking Orbiter Image 516A23)

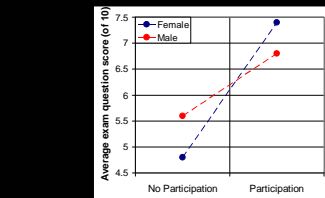


FIGURE 6: Histograms of scores on an exam question about stratigraphy, comparing students who participated in a specifically associated in-class activity (n=135) and those who did not (n=52).

FIGURE 7: Difference between female and male gain from participation in the stratigraphy in-class activity.

STUDENTS WHO ENGAGE DURING CLASS PERFORM BETTER ON HIGH-STAKES EXAMS

WHAT HAPPENS DURING CLASS?

- Every class period includes at least one activity that requires students to focus on a key concept or important process within a limited time, talk with one another and produce something written. Examples include:
 - Use parallax to determine the distance to an object in the room
 - Compare internal structures of two planets with different average densities
 - Interpret a sequence of events by examining stratigraphic sections and surface images of Mars.
 - Evaluate paleomagnetic and age data to decide whether the "tired hotspot" model works for the Hawaii-Emperor seamount chain
 - Construct positive/negative feedback loops after various climate perturbations

WHAT ARE THE BENEFITS OF IN-CLASS ACTIVITIES?

- Breaks up the class time
- Opportunities to meet and talk with other students (social benefit)
- Opportunities to make mistakes in a low-stakes setting
- Students have to focus on concepts within a limited time period
- Student answers and discussion reveal common misconceptions
- Students get immediate constructive feedback and discover their own misconceptions
- Students have opportunities to teach and learn from each other (as in Mazur, 1996)
- Produces a written record of student thinking

ARE IN-CLASS ACTIVITIES EFFECTIVE?

Students who participated in greater than 75% of the in-class activities scored about 9-10% higher on high-stakes exams than students who participated less than 75% of the time (Figure 4; p-values << 0.001). All in-class activities are made available to all students before exams.

MATCHING GOALS, ACTIVITIES & EXAMS

Activities are designed to be linked to learning goals, and high stakes exams are designed to assess student achievement of learning goals. For example, one learning goal in this course is: "Apply principles of relative dating to decipher geologic sequences of events". To address this goal, during an in-class activity, students write a geologic history, using relative time, of (1) a fictitious stratigraphic section, and (2) an image of the surface of Mars with volcanoes, craters, lava flows and cracks (Figure 5). On an exam, students are asked to write a history of a different fictitious stratigraphic section. Students who participated in the activity scored on average 20% higher on the matching exam question (Figure 6; p-value <<0.001).

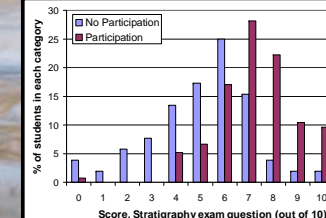


FIGURE 6: Histograms of scores on an exam question about stratigraphy, comparing students who participated in a specifically associated in-class activity (n=135) and those who did not (n=52).

WHO BENEFITS MOST FROM IN-CLASS ACTIVITIES?

Female students who participated in the stratigraphy activity scored significantly higher on the associated exam question than female students who did not participate (Table 1; Figure 7; p-value <<0.001). Comparison of parallel groups of male students shows a smaller but still significant gain for males who participated in the activity (p-value = 0.02). These preliminary data indicate that gender may influence the effectiveness of these in-class activities and that the activities may help female students more than male students. Students in these groups are self-selected (they chose to come to class or not), to test this idea fully would require a controlled experiment.

	Male	Female
Participation	6.8	7.4
No participation	5.6	4.8

TABLE 1: Average scores on the stratigraphy exam question for students grouped by in-class activity participation and gender.

FIGURE 7: Difference between female and male gain from participation in the stratigraphy in-class activity.

WHAT DO STUDENTS THINK?

On an end-of-term survey, students were asked three questions regarding the in-class activities. Students regarded the activities as helpful for learning (Figure 8) and challenging (Figure 9).

FIGURE 8: Students rate the activities generally highly, in terms of helping their learning (n=68).

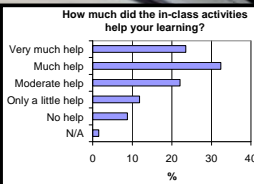
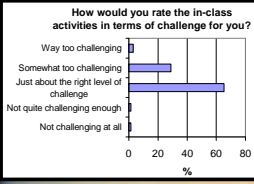


FIGURE 9: Students rate the activities on the "right" side of challenging. Only two students reported the activities were not challenging enough (n=66).



The third question was... "Any comments about the in-class activities? Should they be kept? Expanded? Decreased?" Responses run 4:1 in favor of keeping the activities at about 1 per class.

Example student responses:

- "Sometimes it is good to try and do things without knowing the answer and just trying to really think about how it would logically happen"
- "I REALLY liked how it broke up the class. I made the class seem a lot shorter and more fun."
- "Most of the activities were beneficial in having students apply multiple concepts to solve the activities. Were very good for direct, hands on application of class material. All activities were enjoyable."
- "I liked in the class activities where there were no right answers and people could propose their own theories. For example "what was the last ice age like?" or "How could we increase the planet's temperature further?"
- "They encouraged group work and critical thinking."
- "I liked how we were able to interact with our neighbours in order to solve the problems posed to us...this was a great way to meet new people and a great way to learn from one another"

On the other hand... "I would get rid of the in class activities. Lectures are more helpful for learning"

SUMMARY

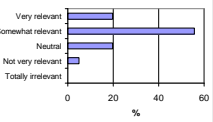
- Students who prepare regularly and participate regularly benefit on high-stakes assessments
- Students recognize the benefits of pre-class preparation and support the requirement
- Students recognize the benefits of active focus on important concepts during class time
- < 6% Most students rate this experience as relevant to them

RECOMMENDATIONS:

- Effective pre-class preparation should be meaningful, challenging, and extend what's possible in class, not duplicate class time.
- In-class activities need to be designed to be challenging enough that students are likely to make mistakes or omissions and discover where their understanding breaks down.
- For a critical mass of prepared and participating students, provide incentives (marks) and produce records, either electronic or hardcopy.

ARE EARTH SCIENCES RELEVANT TO NON-SCIENCE STUDENTS?

Please rate this course based on how RELEVANT you think this experience is to your future life.



References:
Mazur, E., 1996. Peer Instruction: A User's Manual. Prentice Hall, NJ.
Novak, G., A. Goun, W. Christian, and E. Patterson, 1999. Just-in-Time-Teaching: Blending Active Learning with Web Technology. Prentice Hall, NJ.
Acknowledgements:
Thanks to the Science Education Resource Center and Carleton College, Northfield, MN. The activities from this course and a more detailed course description are posted at <http://www.eos.ubc.ca/teach/teach>. Thanks also to the Carl Wieman Science Education Initiative at the University of British Columbia for inspiration.
For copies of all in-class activities, contact Sara Harris at sharris@eos.ubc.ca