<u>Active learning strategies for enhancing the integration of geoscience and engineering</u>

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My current position in the Earth, Ocean and Atmospheric Sciences Department (EOAS) at UBC involves course, curriculum and instructor development for geoscience as well as engineering courses, and I also teach applied geophysics. EOAS administers both science and engineering degrees, and students in each program take many of our core courses together, including the senior three week field school. Therefore I am fortunate to work in a department in which engineering and geoscience are naturally integrated.

To my mind, integrating engineering and geoscience is basically all about "increasing complexity" and "adding context". This is a shift from teaching routine problem solving or facts-based skills towards helping novices think and act more like experts. My approach to facilitating this shift involves reducing content delivery (lecturing or generating "material") in favor of constructing activities that use real settings and professional information as well as basic knowledge about math, physics, etc. Ideally, activities should make thinking visible so that both students and instructors can react to it productively. Here are two specific examples of strategies to support this approach.

A few years ago, I completed a collection of online resources about applied geophysics. One objective was to develop self-contained activities that emulate professional decision making. In one example, the student determines whether seismic surveys are suitable for a given site characterization task. At each stage of this somewhat game-like exercise, information is read, corresponding activities completed, then decisions are made using branch point buttons. Feedback is provided for every possible choice so that students learn directly from mistakes just like in the real world, but in the safety of a simulated setting. Six experimental interactive case studies or "action mazes" can be found in the Applied Geophysics Learning Objects repository ([i]). The scenarios were built using a free tool called "Quandary" ([ii]).

As another example, we incorporated real but redacted consultant's reports into two lab exercises in a hydrogeology course for third year geoscience and engineering students. It took several iterations to discover which aspects of these types of writings beginners could use and which contained too many hidden assumptions that were familiar to experts but obscure for novices. To help students find and use the information, an online quiz was developed to guide student reading rather than to test specific knowledge. The types of questions used for this task can be seen in reference ([iii]).

Why these approaches are valuable in preparing students for the workforce

Enhancing active learning supports the integration engineering and geoscience by helping instructors to shift from the old "topics list" perspective, towards learning goals that reflect what students will be able to DO as they grow in expertise. Developing activities involves careful task analysis to articulate exactly what is involved when designing or making decisions. This helps to (a) identify "expert blind spots" (aspects that are implied or assumed by experts) and (b) define frameworks that students can use as learning guides and when applying knowledge in new settings.

Mixing practical, fundamental, and scientific aspects is also positive motivationally and enables opportunities for students to carry out "preparation for learning" or "discovery" exercises. These involve first encountering the problem without sufficient knowledge to solve it so that the challenges and priorities can be recognized. Subsequent learning then becomes more efficient and more permanent.

These kinds of more “mature” thinking skills are desired by employers, as was shown by a hiring practices study (reference [iv]) we carried out in 2010 at a large mining and exploration trade show.

Ideas for building upon this base to strengthen integration of geoscience and engineering

Integrating engineering and geoscience is easier when there is both discipline specific expertise and knowledge about how learning happens within the particular discipline. This so-called “pedagogic content knowledge” can be improved either with a little focused support from geoscientists or engineers who also have expertise in post-secondary science education, or by encouraging faculty members in a department to participate in mentoring and collaboration programs. Personally, my earlier experiences as an electrical engineer, oil, gas and minerals exploration geophysicist, and in academe, combined with recent expertise gained in science education, have all helped improve my ability to integrate engineering and geoscience in my teaching, and to help others do the same.

Integration efforts would also benefit from more reliable measurements of the effectiveness of specific teaching and assessment strategies, including impacts on various demographics. Pedagogic research can be time consuming, but small scale strategies are possible. For example, we routinely use surveys with short, focused questions to rapidly improve strategies such as the use of permanent learning teams. We also incorporate pre-post testing into normal assessments in order to compare conceptual understanding before and after a course, module or activity. Results can be used to demonstrate or improve efficacy of teaching strategies.

Scaling up the integration of geoscience and engineering for larger numbers of students is another challenge. The action mazes, and quizzes used for guiding first encounters with professional readings mentioned above were both built partly to address this challenge. More research is needed however to determine whether such innovations do in fact improve the reliability and efficacy of self-assessment, evaluation, and delivery of feedback.

After six years of working as part of the EOAS science education initiative, I have seen faculty shift from a content delivery focus towards a student-centric, active learning perspective. Students now spend more time wrestling with higher level concepts, they benefit more from rapid, useful feedback from themselves, their peers, and the instructing team, and they graduate having learned to incorporate the practical and theoretical perspectives of both engineering and geoscience. As an added bonus, faculty have also found that their time in class, and their relationships with students, is more enjoyable, more professional, and more productive.

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[i] Action maze activities are items 20, 21, 22, 26, 27 and 28 at http://urls.bccampus.ca/h6
[ii] http://www.halfbakedsoftware.com/quandary.php
[iii] http://eos.ubc.ca/research/cwsei/resources/Piteau-questions-only.pdf
[iv] https://circle.ubc.ca/handle/2429/37246