**Techniques to Teach Sustainability in Multi-Disciplinary Classrooms Comprised of Engineers, Geoscientists, and other Disciplines**

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I believe teaching sustainability to engineering and geoscience students in integrated courses requires new approaches to course planning, lesson development, pedagogy, student expectations, and assessment. I have had experience teaching to multiple disciplines in integrated classrooms in three different sustainability-focused courses offered multiple times. One challenge I have noted is the need to reconcile differences among students from engineering versus geoscience versus other disciplines. I have learned that differential teaching and learning (DTL) must be factored into the course plan and delivery. The purpose of this essay is to describe DTL and to present a few of my experiences with techniques appropriate when significant background differences exist among students in the course.

DTL is a common circumstance in multi-disciplinary classrooms at the upper division and graduate levels where students from different majors enter a course with different levels of knowledge, skills, expectations, capabilities, and pre-conceptions. In my first efforts, I found teaching to this diverse set of students with approaches I have used in my previous engineering-student only courses were not as successful because the assignments and activities were being designed with a single discipline focus or being pulled from my past single-discipline teaching experience. I had to adjust my teaching and learning techniques. Teaching techniques that have been successful for me to teach to diverse student cohorts include: (1) providing clear learning objectives, (2) co-teaching (from course planning to course delivery), (3) using project-based learning, (4) facilitating communication, and (5) incorporating linked learning activities.

Having clear course and lesson learning objectives is a critical first step for aligning the expectations and foci of students in multi-disciplinary classrooms. It is important for the lesson learning objectives to be provided to the students before class activities for that lesson are assigned or occur (i.e., before reading, homework is assigned and of course before the class session). It is also important to present the collection of lesson learning objectives in a hierarchical manner so students from the different disciplines can see how the content in a class and from several class sessions in a module is linked together. Engineering students at the University of Utah are moderately familiar with learning objectives, but students from most other majors have not been widely introduced to lesson learning objectives. The use of them helped all students in the class come adequately prepared and focused to conduct the lesson.

I believe DTL challenges associated with teaching broad sustainability topics to a multi-discipline classroom may be mitigated if the course is co-taught by instructors from different disciplines. I have co-taught three courses multiple times and in each case the interaction with my co-instructors was essential in creating a course plan that could appeal to engineers, geoscientists, and other majors, accounted for our teaching styles, and provided a coherent sequence of topics and lesson activities for the students. In all courses classroom activity has included discussion time and this is where the co-teaching is essential to a set of students from different disciplines – to provide them role models of disciplinary interaction appreciating the perspective of other disciplines. This is especially essential if the disciplines of the students are disparate (engineering, science, humanities, and social sciences) where pre-conceived notions of the other majors inhibits respect/value of opinions initially.

Another DTL technique I have had success with is project-based learning (PBL). My experiences with interdisciplinary teaching have included both PBL experiences and traditional classroom activities. But, I have found PBL to be the most effective. Using projects enables the instructor (or instructor team) to set the scope of the projects to require a range of disciplines to participate. This helps to illustrate not only real-world projects where multiple disciplines typically must interact, but also the value of other disciplines to successfully complete projects. This is even more essential for sustainability topics and projects that are inherently multi-disciplinary. I have found students in integrated sustainability courses will learn from each other (even from disparate disciplines) if there is a clear project that requires them to integrate their efforts. Sustainability projects come in many shapes and sizes but the need for a range of disciplines can nearly always be found. Finding ways to integrate engineers with geoscientists with other majors is a challenge, but accomplishing it with a project-based experience has worked well for me.

Communication is a critical tool to teach sustainability topics to integrated classrooms. First, as mentioned previously it helps for the instructor (or instructors) to have the broad knowledge across disciplines to lead discussions and lecture effectively. As a civil engineer I have had to learn a great deal about geosciences and other disciplines to improve my teaching effectiveness in multi-discipline classrooms. I have students from different disciplines and from different backgrounds enter a course and have different thoughts on what is the expected workload, what is the expected quality of work, and how they communicate their thoughts. It is important to bring the entire class to a common ground. In the case of course mechanics, instructors must role model working with multiple disciplines. The instructors must clearly state the expectations and continuously reinforce them. And the instructors must work with students to prepare homework and project submittals to match a common structure that meshes the different disciplines and forces students to incorporate approaches and ideas from different disciplines. Second, students need to be engaged in activities with other students that require extensive communication. I have used think-pair-share and small group discussions and made sure the pairs and groups have multiple disciplines. This helps to build collegiately among the different disciplines and helps to develop a common language while accomplishing lesson learning objectives.

Lastly, a very effective technique to integrate engineers, geoscientists, and other majors is to use linked-learning activities. Linked-learning activities typically involve independent courses joining in learning activities that require skills from multiple disciplines to achieve the total problem solution. I have accomplished this with homework assignments, projects, and online discussions that engage students from multiple courses taught by different instructors. This is a logistical challenge and most importantly requires having excellent working relationships with the partner instructors and also a solid working knowledge of the other disciplines and course topics involved.

In sum, in addition to the five specific techniques described above a critical element of effective teaching of sustainability to engineers, geoscientists, and other disciplines in an integrated classroom is to adapt and adjust course content, teaching techniques, learning activities, and expectations as the course progresses. I rarely have to do this for a Civil Engineering course, even when offered for the first time. But I have had to do it for my interdisciplinary sustainability courses, even those that I have taught multiple times.