Session

A WALK ON THE MOON:
Interdisciplinary, Inquiry-Based Learning Theory into Practice

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Introduction

Academic disciplines and corporations whose basis lies in science and engineering are calling for diversity in the student body and work force, including women and other under-represented groups (Ramsey et al, 1997), one that is comfortable working in teams (Frost, 1998) and willing to engage in collaborative problem solving directed at complex or wicked problems (Turner, 2002). Turner says: "This rethinking involves the nature of the science that we do (more integrated), the way that problems are defined (collaboratively), the role of the scientists in the process (more engaged), and the tools for delivery (more user friendly)". These economic and social pressures require that educators rethink or redesign how material is presented to students. One approach to implementing these changes is to modify the traditional, lecture-based science and engineering education technique to include one of guided inquiry and multi- or inter-disciplinary project performance. We have designed an interdisciplinary science and engineering seminar course to investigate this new approach. Our expectation is that in offering an alternative learning environment, we might reach more women (Hunsaker, 1996, Shirley, 1999, Huang et. al., 2000), under-represented minorities[1] and traditional students, encourage them to persevere in their fields and offer them some useful tools for their career development.

The course was developed as part of a National Science Foundation (NSF) grant for the advancement of women and under-represented groups in science and engineering. The NSF-funded project is entitled FORWARD in SEM (www.seas.gwu.edu/~forward). This project aims to increase the numbers of women and individuals from underrepresented groups in advanced science, engineering and mathematics (SEM) studies and careers. Our particular focus is on the bridge between undergraduate and graduate studies in SEM fields. We have developed activities designed to encourage women and students of other underrepresented groups to consider graduate studies, apply to graduate school and, once in, stay in and complete advanced degrees. The project has five activities: a workshop for sophomores and juniors considering graduate school, the interdisciplinary seminar course described here (A Walk on the Moon), a summer research competition for first year

[1] Under-represented minorities include ethnic minorities and students with disabilities.

graduate students, a mentoring network, and a program for improving Deaf access to SEM careers.

The course was implemented for the first time in the first semester of 1999 and was repeated in 2000. Both times the course was offered at George Washington University and Gallaudet concurrently.

Theory into practice

Theory

Problem-based learning in science: Problem based learning shifts the attention from the teacher-centered to a student-centered design. The structured learning environment of lecture-based instruction sees teaching as transmitting and learning as receiving, is presented from the perspective of the teacher, is usually linear, and is often organized as going from parts to whole. A flexible problem-based learning environment develops from the perspective of the student, is coherent and relevant for learners and puts the teacher in a role as facilitator helping learners develop understanding from the whole concepts to their native parts (adapted from Center for Problem Based Learning website).

The value of a team: Research notes that solo status (i.e. working alone) has more detrimental impact on women and under-represented minorities than on white males (Thompson and Sekaquaptewa, 2002). A team is more than the sum of the parts. As learners engage more complex problems, they need to draw on a multitude of expertise. Carl Larson and Frank LaFasto (LaFasto, 2000) in their landmark study of excellent teams, drawn from experiences as diverse as the Mt. Everest Expedition of 1985 to the Boeing 747design team, identified eight common characteristics of high-performing, face to face teams: A clear goal, a results driven structure, competent members, unified commitment, collaborative environment, standards of excellence, outside support and recognition and leadership. Educational experiences that include team efforts are stressed by accrediting associations. ABET criteria (www.abet.org) suggest (that) under criteria 3 of Program Outcomes and Assessment, that "students must be able to function on multi-disciplinary teams." Moreover, ABET urges student become involved in contemporary issues and understand the impact of their engineering on social and global issues. These latter goals are related to team involvement as defined by Turner (2002) when he points to the role of integration and collaboration in global engineering.

Taking risks in solving complex problems: Women typically choose disciplines in which they believe they will do well. Discussions about the leadership qualities necessary for successful women indicate that the ability to take risks is key (Mills, undated, Howell, 1993, Based on Brown University website). Moreover, they often perceive their abilities in science, engineering and mathematics to be less that those of their male peers. They, as well as other students who do not typically pursue science, engineering or mathematics, would benefit from increasing exposure to more real-life learning situations where they must manage risk in solving complex problems. Their risk taking brings personal challenge and adventure to their academic studies so learners associate their developing skills/knowledge with increasing power, confidence and ability to deal with challenging situations.

The need for writing and communication across the curriculum: Every supporter of engineering and science education assessment (i.e. ABET, CSAB, ACS) indicates the need for students to communicate clearly in written reports and oral presentations. As early as 1985, Anne Herrington was indicating the need for students to engage in discourse, to practice writing conventions of their discipline and to use the process of writing to clarify their understanding of abstract concepts. Beyond that, writing and speaking clearly and directly is a skill valued by potential employers.

The value of non-traditional learning environments: Non-traditional environments for teaching and learning include a multitude of definitions. We take this to mean the use of non-lecture based sessions with a heavy reliance on on-line, self-directed learning. Self-directed learning has been described as "a process in which individuals take the initiative, with or without the help of others," to diagnose their learning needs, formulate learning goals, identify resources for learning, select and implement learning strategies, and evaluate learning outcomes (Knowles 1975). True self-directed learning occurs when the learners, not the teacher nor the institution, direct the choice of both the learning objectives and the means or avenues of learning. Setting an environment that encourages self directed learning require that the educator engage in some of the following:

1. Help the learner identify the starting point for a learning project, discern relevant modes of examination and reporting and manage the experience.
2. Help learners acquire the needs assessment techniques necessary to discover what objectives they should set.
3. Teach inquiry skills, decision making, personal development, and self-evaluation of work.
4. Help match resources to the needs of learners and help learners locate resources.
5. Help learners develop positive attitudes and feelings of independence relative to learning.
6. Use techniques such as field experience and problem solving that take advantage of students' rich experience base.

Women and under-represented minorities and SEM: Studies (Huang et al, 2000) indicate that the gender gap in SEM closes when women (and by extension, minorities) are confident about their abilities in SEM. Women report that they need to feel that they are taken seriously as part of the learning process (Howell, 1993). Furthermore, the learning environment for women may differ from that experienced by men (Leveson, 1991). Professors remembered the names of men better, called on them more, asked them more challenging questions, listened and positively responded to them more, etc. Both men and women teachers display this behavior.

Practice

Choose a rich topic: the topic for the seminar course was chosen to be the Moon for several reasons. The topic is rich and addresses a broad crosscut of science and engineering disciplines. Furthermore, ethical, environmental and policy issues play a significant role as well. The topic provides a level playing field for participants in the course: both faculty and students are unfamiliar, in terms of expertise, with the topic. The remoteness and perceived strangeness of the Moon and the 'blank slate' that the Moon offers for current as well as futuristic technological applications also contribute to this equality. This equal access issue is important to our target audiences: women and underrepresented groups such as the Deaf and minorities suffer from the real or perceived impression that they are less knowledgeable or able in a particular technical discipline (Leveson 1991, Howell, 1993). Removing barriers to these equalities has been a primary goal of this project. Finally, the topic of the Moon and space exploration is fascinating, exciting and current, as live data from the Lunar Prospector mission is available to the students through Moonlink (www.moonlink.com).

Use an interdisciplinary team of faculty who are concerned about women and under-represented minorities: the current team consists of four faculty members in different science and engineering departments and different universities. As such we have chemistry, physics, computer science and mechanical and aerospace engineering represented. This allows for a broad pool of expertise in equally important areas that often interplay. Our resource pool is even larger through our respective contacts and research areas. Information from all four faculty members is communicated electronically and through shared lecturing. The faculty must be trained or aware of engaging methods for delivering information to students. All of us have participated in the University of Wisconsin System Women and Science Program Curriculum Reform Institute (www.uwosh.edu/programs/wis/cri.htm), where we have learned valuable tools and techniques for improving science and engineering education.

Make use of electronic communication tools: course materials are collected on the Prometheus (http://prometheus.gwu.edu) electronic courseware developed at GW. This application facilitates computer supported cooperative work through email, discussion lists and shared files and easy access to World Wide Web and Internet (WWW&I) materials through directly clickable links. A range of multimedia references may be used, including video interviews of professionals, who serve as role models and become part of a community for the students. For example, shown at right is a still image from a video interview with MIT professor Dava Newman, an expert in biomechanics of astronaut extra-vehicular activities and the effects of reduced gravity environments on astronauts. This courseware provides a communication tool for the distributed audiences of the course at the different institutions, including live videoconferencing. This web-based format for the course establishes a high standard for learning and self-guided inquiry, creates communities of science learners, and provides opportunities for scaffolding (Guzdial et

al., 1998): educators can provide students with as little or as much support as deemed appropriate at the participant sites.

Make the course project-oriented: students are given a request for proposals (RFP) for a mission or any subsystem of a mission to, on or around the Moon. The students are expected to deliver a proposal by the end of the course. The proposal must be presented orally before the class and a group of experts and must be submitted electronically in the form of a written document. Several other requirements are incorporated into the RFP: in particular, students are expected to make use of recently acquired data from the Lunar Prospector (LP) and/or Clementine mission(s).

Use a non-traditional approach: no formal lectures are held. Instead, the approach of guided inquiry and discussion, group and individual research are used to learn about the Moon and science and technology. The self-guided inquiry and research is done mainly through the WWW&I, though library research, networking and personal contact are also encouraged. The use of the WWW&I is a key ingredient in leveling the playing field for disadvantaged, disabled or non-confident participants such as those we are targeting.

The group inquiry in class is designed to launch the students into their own investigations. In order to prepare the students and provide them with the skills necessary to deliver a proposal, the course provides weekly investigations of the pertinent topics or disciplines related to a Moon mission. These are listed in the class outline in Figure 1. The students are expected to generate the "organizing questions" (OQs) as a group in class to begin forming a background foundation in the discipline. This approach promotes discussion and cooperation among the group. The students then spend some class time researching answers to the OQs on the WWW. The instructors then guide a class discussion on the topic, with input from the students' search results, using prepared lecture material as a guide to ensure coverage of the pertinent information. Notes on the lecture material are posted on Prometheus after the class session.

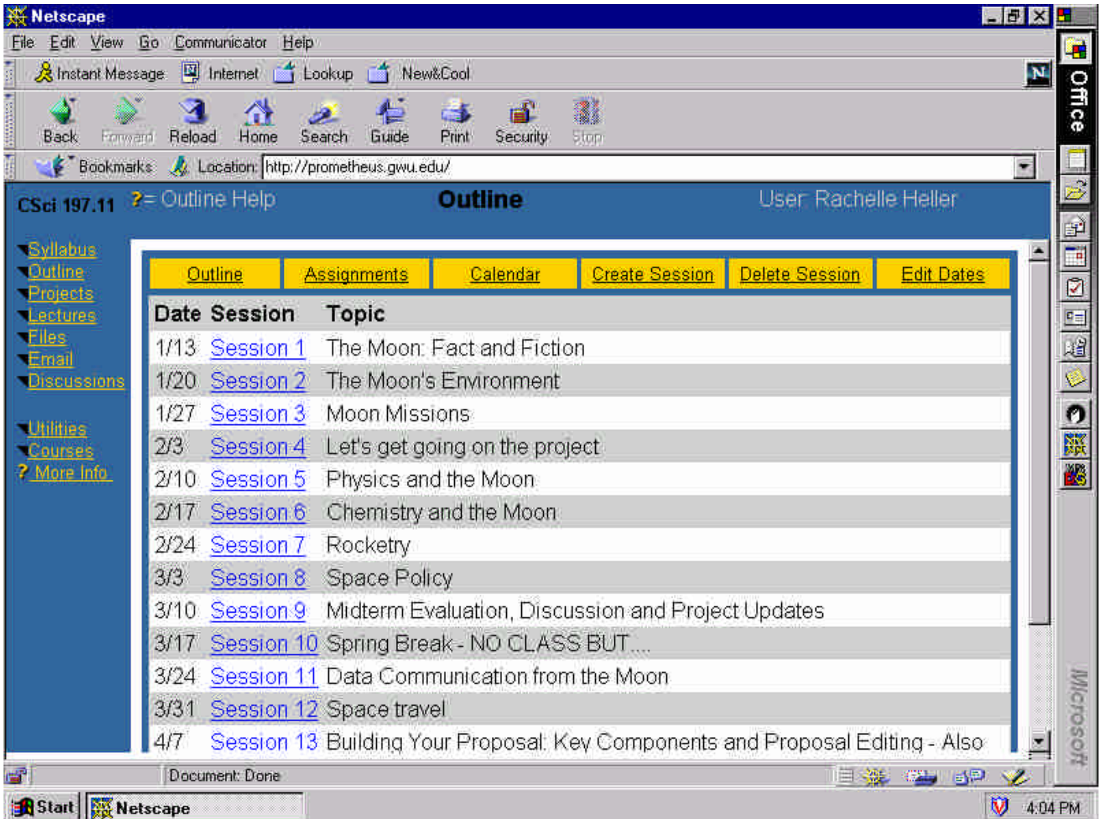

Figure 1: Course outline as viewed in Prometheus[7] (electronic courseware application).

This format is enhanced by having guest lecturers, who are working in fields closely related to the topic, in this case space. Among our visitors were:

- Dr. Mario Acuna, physicist at the NASA Goddard Space Flight Center. As one of the developers of the Lunar Prospector instruments, Dr. Acuna gave the class a close-up view of the significance of space missions, their science and engineering, while providing us with a physics tutorial to enable us to grasp the importance of the issues.
- Dr. Charles Camarda, US Astronaut. Dr. Camarda gave an overview of manned space missions, past, present and future and provided specific insight into the interdisciplinary nature of engineering hardware design for these missions.
- Dr. John Logsdon, Director of the GW Space Policy Institute. As a recognized expert on US and international space policy, Dr. Logsdon was able to paint us a picture of the political drivers for space programs and the unique historical significance of the race to the Moon.

In each case, the guest was instructed to not lecture, but rather give us the basics of the topic through answering questions from the group. The overriding unifying thread in each of the guest presentations has been the interdisciplinary nature of this work, something that is not traditionally taught at the university level.

Help the students build some career skills: the course uses presentation opportunities for science and technology learning, for development of SEM and professional career skills, for confidence and self-esteem building, and for skills in critical assessment of technical merit. The students learn to give professional oral presentations and learn to critique other presentations for their technical merit. The students also learn to write technical proposals, enhancing their written and electronic communication skills. The students must analyze data, design and analyze a science or engineering process. Teams are created to present, design and solve proposals (RFP) for a mission or any subsystem of a mission to, on or around the Moon. The teams are populated with all levels of student from freshmen to graduate and from all areas within the Engineering program and science areas in chemistry and physics. The students have the opportunity to learn to work in these diverse teams and appreciate the challenges of other disciplines as well as those of merging disciplines.

Results

Student Outcomes

The students in all cohorts participated in multidisciplinary projects and submitted respectable proposals. The students were paired by different disciplines and, when possible, different levels. Many of the students reported that they enjoyed having the opportunity to learn in a discipline out of their major. Most students reported that the course helped them to realize the enormous scope of their disciplines, however only half reported that the course changed their attitudes about engineering (in the case of the engineering students). In each class, it seems there is at least one or two motivated students who really appreciate the interdisciplinary aspects of such a project. Required anonymous comments submitted weekly by the students showed significant progress in intellectual maturity. For example, in the early weeks of the course, students answered the question "I sat here for the entire class period and I still don't know…" with empty lines or unrelated jokes. As the course went on, they indicated such concerns as how to relate their knowledge of gravity to escape velocity.

Overall Results

The use of the electronic courseware is an excellent means of getting students and faculty off to a productive and motivated start: both post interesting links to pertinent information in the first part of the semester, thereby creating the atmosphere of a community of learners. Certainly, the most difficult issue for both students and faculty is the non-traditional format of the classroom sessions. The students need to be motivated and mature to follow up on the material after the sessions. Faculty have to resist reverting to the traditional lecture format. While both students and faculty need time to get accustomed to this non-traditional approach, both learn to take risks. Since they are responding to the RFP based on an open-ended question with no right or wrong answers, students have a vehicle with which to explore. They have to grapple with topics of complex scope, discover that science is not a set of closed experiments but a process. Professors also learn to take risks. A Walk on the Moon is a course in which they are not the expert. It gives the professors an opportunity to say "I don't know, let's find out together." Professors are challenged to think clearly and uniquely about topics, making the explanations accessible to all levels of students.

We have found the experience of merging science and engineering fields in the classroom to be rich and rewarding. There is no shortage of available resources, be they electronic or written documents, venues for field trips or people willing to share their knowledge and experience with students. We feel the students and the faculty have benefited tremendously and have had their traditional education paradigm shaken enough to generate serious questions in their classrooms and in their lives. All faculty have incorporated aspects of this course into their traditional class offerings. The anonymous comments, called one-minute madness, are used by all each week as a way of monitoring classroom learning. Faculty continue to use real-world based projects in the classroom and rely, as often as possible, on outside speakers for additional motivation.

Conclusions

The design and implementation of an interdisciplinary inquiry-based course has been presented. A number of methods for constructing such a course have been suggested. The non-traditional format of no formal lectures seems to be successful: 1) in preparing students for real engineering situations that they might encounter in their careers ahead of them and 2) in making them more comfortable in the engineering field. While we did not distinguish a difference in attitudes between men and women in the offerings of this course, we do believe that the novel format allowed for greater diversity within the classroom: the built-in impression of "no one is the expert" allows for greater self-confidence in students to express themselves and hence to learn.

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Biography

Catherine Mavriplis is an associate professor in the department of mechanical and aerospace engineering at the George Washington University. She conducts research in computational fluid dynamics, combustion and MEMS and continues her interest in supporting women and underrepresented groups in science and engineering through interdisciplinary approaches to research and education.

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