AC 2007-390: BOUTIQUE ENGINEERING: STUDENT LEARNING IN A MULTIDISCIPLINARY ENGINEERING CONCEPTS AND METHODS COURSE

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Boutique Engineering: Student Learning in a Multidisciplinary Engineering Concepts and Methods Course

Introduction

EGN1008C Engineering Concepts and Methods is a first year course that has been designed and team-taught by a multidisciplinary troika of faculty (one bioengineer, an environmental engineer, and a civil engineer) in the fall semester of 2006. This paper provides an overview of the overall philosophy, content, and evaluation of assessment results obtained in our first offering of EGN1008C as a highly integrated and multidisciplinary "gateway" technical course to our three curricula in bioengineering, environmental engineering, and civil engineering.

Overview

The new U.A. Whitaker School of Engineering at Florida Gulf Coast University (FGCU) has been launched as a truly multidisciplinary engineering education endeavor with simultaneous development of three B.S. degree programs in bioengineering, environmental engineering and civil engineering[1]. This highly focused "boutique" effort in creating three interwoven and relatively specialized engineering degree programs based upon best practices in both discipline-specific and multidisciplinary engineering education presents unique challenges and opportunities for promoting and assessing student learning. Once completely developed, eight common courses in engineering will bring students from the three majors together for integrated, lecture/lab experiences and activities. The cohort of 100+ students moving through our freshman sequence this year will ultimately make up many of our first and second classes to graduate from each of the three degree programs in spring of 2009 and 2010.

In designing our courses, curricula and the overall undergraduate engineering experience at FGCU our faculty have embraced the recommendations of the National Academy of Engineering (NAE) for adapting engineering education in the Phase I report <u>The Engineer of 2020 – Visions of Engineering in the New Century</u>[2], and the subsequent Phase II report <u>Educating the Engineer of 2020 – Adapting Engineering Education to the New Century</u>[3]. Our freshman year two-course sequence of EGN1006 – Introduction to the Engineering Professions, followed by EGN1008C Engineering Concepts and Methods has been implemented in keeping with the NAE recommendation of introducing engineering design, engineering problem solving, and the concept that engineers are servants of society as early and as interactively as possible. Thomas Friedman's popular commentary <u>The World is Flat</u>[4] has served as additional inspiration for crafting a curriculum that is responsive to additional NAE recommendations, whereby engineers are better prepared to adapt to changes in global forces and trends, and to be leaders in the new "flat world" in the use of wise, informed, and economical sustainable development[5].

Engineering Concepts and Methods, which introduces freshmen to engineering problem solving and the engineering design method, as well as to software tools for engineering problem solving including Excel, MATLAB®, and AutoCAD®, is the first highly technical course for all three of the majors. Exercises and problem sets in all three areas as well as in general engineering and physics have been integrated into course delivery. The course has been structured as a three semester-hour combined lecture/computer-lab experience with four total hours of contact time per week (one hour more than for a purely lecture-based course). Class sessions typically include mini-lectures and/or tutorials, and brief or extended individual or team problem sets. A semester end project carried out in teams of two with the theme of "Smart Houses" was utilized to place the overall subject matter of the class within the broad context of multidisciplinary engineering for the twenty-first century. The course was delivered in the fall semester of 2006 to two separate class sections of students. Assessment and evaluation results from these two class sections are pooled within this paper.

As expected, students entered the course with significant prior experience in the use of Microsoft® Office products, primarily within the Windows® operating system. 98% of students reported prior experience using MS Word, 93% with MS Excel®, and 77% with MS PowerPoint®. While an impressive 41% of students had prior experience using AutoCAD®, only 7% had any previous experience with MATLAB®. At the start of the semester 80% of the students responding to a pre-course survey intended to major in civil engineering, 16% in bioengineering, and 5% in environmental engineering (N=44). In the same anonymous survey, students overall responded to the question "Given your current choice for major, on a 1-5 scale, how certain are you of your choice? (1 is least certain, 5 is most certain)" with an average certainty of 4.2 (standard deviation = 0.8).

Course Content

The primary learning outcomes for the course are that by the end of the semester, working in and outside of class, students will:

- Know the basic steps and strategies involved in approaching solutions to a problem
- Have a basic understanding of the engineering design process
- Be able to use Excel® to create spreadsheets, define and use functions, and to display and analyze data and trend lines in graphic visualizations including 2-d and 3-d plots
- Be able to set up and solve a variety of fundamental engineering problems using Excel®and MATLAB®
- Be able to write and execute MATLAB® programs to solve and visualize basic engineering problems
- Be able to employ AutoCAD® to create fully dimensioned, 2-D engineering drawings
- Develop their engineering technical communication skills in preparation of their assignments, quizzes and exams.

Assessment of student achievement of these outcomes can of course contribute to broader programmatic assessment and evaluation across a number of the ABET Criterion 3 Program Outcomes. Out initial focus with this first course offering has been to utilize assessment results to establish baseline evaluation of student skill sets in the "use of modern engineering tools " (3k) and in communication skills (3g).

While there are certainly a number of good textbooks available, the fall 2006 offerings of EGN1008C required Larsen's Engineering with Excel, Concepts and Examples[6], Gilat's MATLAB®: An Introduction with Applications, 2nd Ed[7], and Dix and Riley's Introduction to AutoCAD, 2nd Ed[8].

In-class exercises and homework sets in the course incorporated problems from general science and engineering, as well as from bioengineering, civil engineering, and environmental engineering. Larsen's Engineering with Excel text, for example, contains a series of problems which assist students with learning how to incorporate formulas into spreadsheets that relate to fluid statics (i.e. water columns, manometers). This material was placed within a broader multidisciplinary context through discussion of a variety of engineering examples (e.g. importance of venous valves to prevent static pooling of blood in the lower extremities of humans; static pressures at the bottom of lakes and behind dikes; why scuba divers need to breathe pressured air, etc.).

The end-of-semester project theme for the course was "Smart Houses", which was chosen by the instructors as an exciting and readily assessed multidisciplinary theme for ensuring that students in (and across) all of our three majors would be able to identify focused and interesting topics for investigation, and for showcasing their skills in design as well as in the use of Excel®, MATLAB®, and AutoCAD®.

Project Assignment and Topics Chosen

The semester project assignment, in part, informed students that

> …many engineers consider "Smart Houses" to be the future of residential building, integrating designs and technologies that yield increased quality of life for the occupants. Bioengineers, civil engineers, and environmental engineers can all play roles in Smart House design. Smart House features can address for example sustainability, cost effectiveness, health and safety, the environment and resource efficiency, security, and entertainment. From the asphalt or concrete in the driveway, the landscaping around the house, materials used in construction, energy sources incorporated, to integrated house systems that can monitor an individual's state-of-health, Smart Houses represent a fascinating blend of technologies across our engineering disciplines.
>
> For your end-of-semester-project you must identify an existing or potential future design that could be incorporated into a Smart House. You must work on this project in teams of two students from our class. The final deliverable for the project is a professional poster and poster presentation that will occur in a class time slot at semester's end. Your poster must incorporate a number of elements that reflect the skills we are developing this semester in EGN1008C, including: information searching, professionally written summaries of information, use of the engineering design process, and use of Excel®, MATLAB®, and AutoCAD® to convey engineering information and to solve problems. Most homework in the remaining portion of this course will be related to this project. Some in-class exercise time slots will also be devoted to developing components of your project and poster…

Student teams chose a wide range of topics within the Smart House theme, mainly within areas that involved automation and control, energy sources and conservation, and environmental factors. Specific project topics included –

- Climate Control (Electrothermic "Smart" Windows)
- Comforts of a Smart Home (Environmental Controls)
- Earth's Blanket – The Geothermal Pump
- Home Health Monitoring System Using the Sizzle (Secure Server)
- Incorporation of Photovoltaic Concrete in a Smart House
- Let There Be Light (Home Lighting Automation)
- Microphone Array System (For Home Automation Control)
- Renewable Energy for a Smart Home
- Retractable Roof
- RFID in a Smart Home
- Smart Home Entertainment
- Smart House Weatherproofing
- Smart House Green Roof
- Smart House Heating and Cooling
- Smart House – Recycled Tire Asphalt
- Smart House Recycling System
- Solar Conservation
- Solar Panels
- Technologies of Light Automation
- Voice Activation (For Home Appliances)

Assessment and Evaluation

Course assessment included targeted scoring of students' achievement of the course's learning outcomes related to problem solving and design, and in gaining skills using Excel®, MATLAB®, and AutoCAD® via tests, a final exam, and in the semester project. In the final Smart House project poster session (Figure 1), presentations were judged by the course instructors and additional engineering faculty, and a final survey of the students was carried out to obtain their feedback in a number of areas, including the overall value of the course and projects (N=37 valid responses).

On average, student achievement of the course learning outcomes was relatively high. Figure 2, for example, details mean overall scores on the written final exam in the areas of design and problem solving, in use of Excel®, MATLAB®, and AutoCAD®, and in the Smart House project. Anecdotally, students for the most part valued use of the extended contact time in the course for performing in-class exercises. There appeared to be some lack of retention of Excel® skills from the early part of the semester (when that material was introduced) to the end of the course (on the final exam). Students tended to express having the highest difficulty in the course in learning and applying MATLAB®, which is understandable given their general lack of familiarity with not only MATLAB® itself entering the course but with programming in general. This is a challenge that others have also reported on, particularly in courses at the freshman level.[9,10]

Figure 1. A poster session judged by the instructors and invited faculty culminated the semester project.

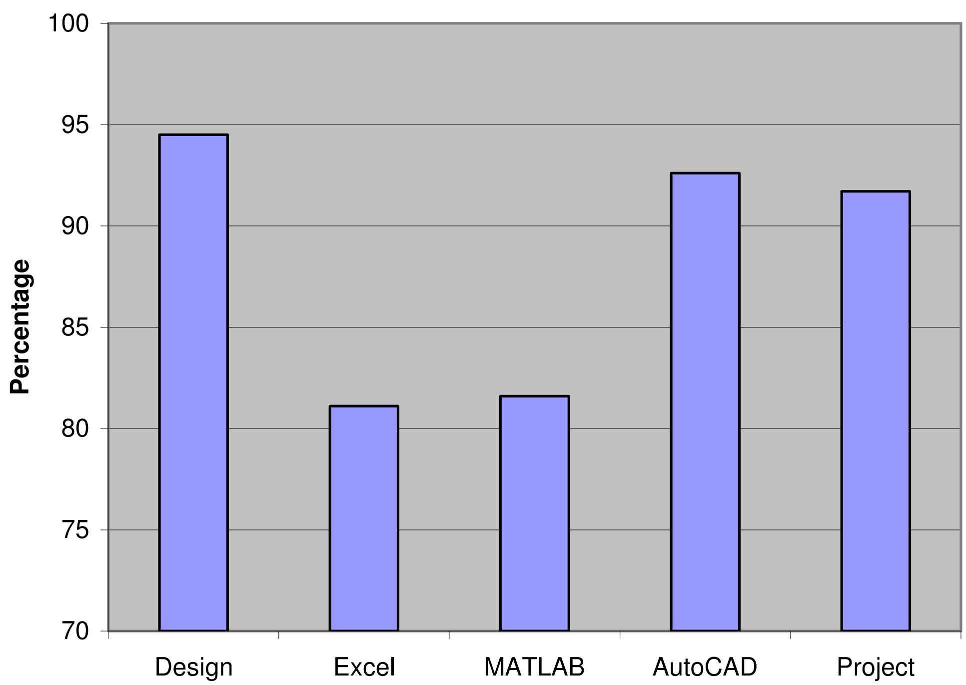

Figure 2. Overall mean scores on the course final exam in the areas of engineering design and problem solving, Excel®, MATLAB®, AutoCAD®, and on the course Smart House project.

Overall students' certainty in their choice of major increased slightly from the pre-course level of 4.2 +/- 0.8 (on a 1 to 5 scale) to 4.4 +/- 0.7 (p=.095 using a one-tailed Student's t-test) at the end of the course, with 16% of students reporting that they changed their choice of major over the semester. Students were allowed to self-select into their Smart House poster teams of two, in part to see if they would form and work effectively in multidisciplinary teams on their own. 41%

of students in fact did form teams with a classmate of a different or unknown (to them) major. 78% of students found the Smart House project “interesting” (16% found the project “somewhat interesting” and 5% “not interesting”) with similar numbers either recommending or not recommending that a similar project experience be included in future course offerings. In responding to the statements “Please rate the overall value to you of the Smart House project” and “Please rate how much the multidisciplinary instruction in this course and the multidisciplinary nature of the Smart House project (spanning different areas of engineering) has been of value to you” (both on a 1 to 5 scale where 1 was “none”, 2 was “a little”, 3 was “some; average”, 4 was “high”, and 5 was “very high”) students overall valued the project with a mean scoring of 3.9 +/- 0.9, and the multidisciplinary nature of the course/project at a mean rating of 4.0 +/- 0.6. Figures 3 and 4 depict the full spectrum of student responses for both of these scorings broken out into multidisciplinary teams and same-discipline teams. While student responses from these two groups were not significantly different (Student’s t-test with one or two tails; p values were >0.1), anecdotally it was clear that some multidisciplinary teams needed to devote more time and effort to their projects to insure that both members of the team could feel content with the project and its outcomes.

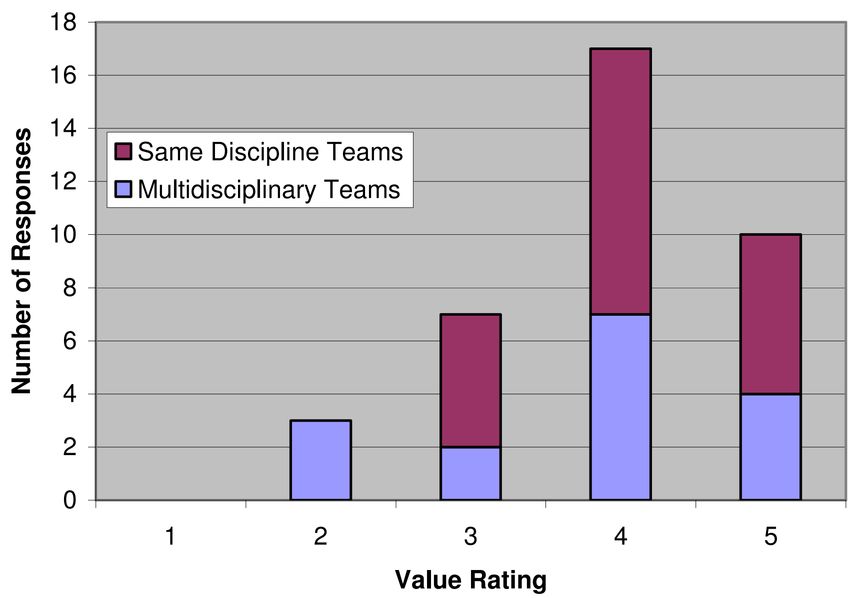

Figure 3. Student ratings of the overall value of the Smart House project where a rating of 1 is “none” and 5 is “very high”.

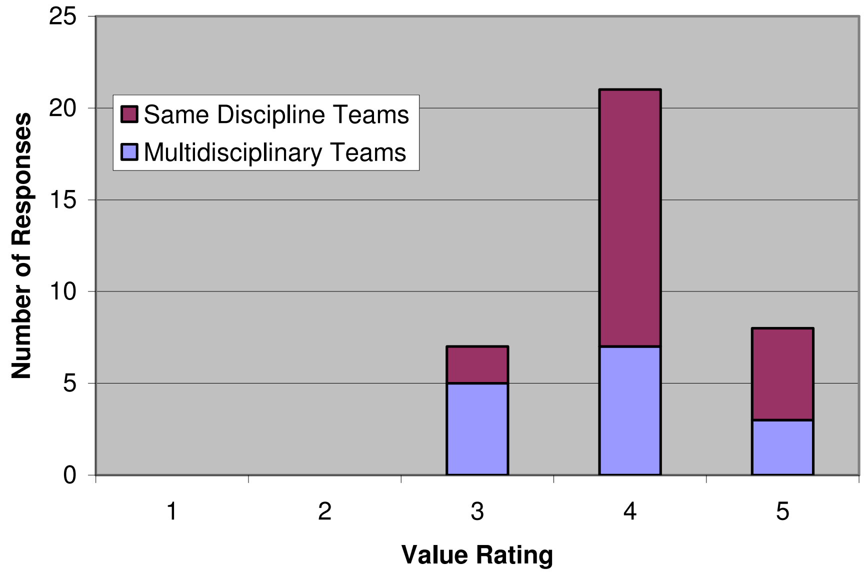

Figure 4. Student ratings of the overall value of the multidisciplinary instruction and Smart House project where a rating of 1 is "none" and 5 is "very high".

Discussion and Conclusions

Students listed a number of aspects of the Smart House project that they valued highly, and some that they did not value. Typical comments describing aspects of value included:

> "the design process and the information attained"
> "the requirement to explore and execute the design process"
> "incorporating all three programs we learned was a good idea"
> "using all three programs – the work in MATLAB® helped me get a better understanding"
> "information I found that I was unaware of"
> "learning to make posters"

In responding to the question "What aspect of the Smart House project was of least value to you?" many students had no response, but some did feel that incorporating MATLAB® or AutoCAD® was difficult and/or just not of general value to them. Varying student attitudes towards learning MATLAB® were perhaps the largest challenge faced by the instructors. It was encouraging that some students who early in the course could easily see the value of learning Excel® and AutoCAD® to solve engineering problems, but who had trouble with motivation to learn MATLAB®, found that the semester project helped them to see "real world" technologies where programming in general (and MATLAB® as the programming tool that they were learning) was needed in order to implement basic aspects of sensing and control.

In conclusion, we have initiated development of a multidisciplinary, freshman level course devoted to introducing engineering design and problem solving along with integration of Excel®, MATLAB®, and AutoCAD® in a combined lecture/computer-lab environment. Incorporation of an end-of-semester team project within a "Smart House" theme carefully chosen in order to place all of the skill-sets being developed, including communication skills in crafting and presenting a technical poster, within a meaningful context to students majoring in bioengineering, civil engineering, or environmental engineering has been very successful in promoting student learning (and motivation to learn).

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