AC 2007-3028: ENGINEERING DESIGN AND COMMUNICATIONS: SUCCESSES AND FAILURES OF AN EVOLVING FIRST-YEAR COURSE

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Engineering Design and Communications: Successes and failures of an evolving first-year course

Introduction

Design is widely considered to be the central and distinguishing activity of engineering. Although technical knowledge is important, so are teamwork, communication and critical-thinking skills, as well as the ability to continually learn and stay current with ever-changing technology. First-year design courses have been added to the curriculum in an effort to introduce students to what engineers actually do while they are also learning professional skills and the engineering design process.

Using design projects to teach engineering skills has been a major innovation in engineering pedagogy. There is strong evidence that team projects and problem-based learning in engineering design courses:

- Maximize student achievement;
- Stimulate student interest in engineering;
- Motivate learning in upper division engineering science courses;
- Increase student retention in engineering programs.

However there are many “soft skills” required in learning design and no consensus on which are most important for first year students, nor which is the best way way to teach them. Some institutions focus on design methods and team dynamics [eg. Harvey Mudd], others on design and writing [eg. Northwestern], and others combine design with graphics [eg. Penn State]. Mount Royal College offers a University transfer engineering program. Thus, our courses must conform with the local University to which most of our students transfer. In design terms, the constraints imposed by the University are that there are two sequential first-year courses, each with 1 hour of lecture time per week, and 4.5 hours of lab time (a 3-hour long lab and 1.5-hour short lab) each week. Students are assessed through individual and group work with approximately equal weight on visual communication skills, oral and written communication skills, and design.

Outside of these constraints, our instructors are free to design the courses as we feel is best for our students. One of the main goals of the courses is to stimulate a “deep approach” to learning, meaning that students should attempt to understand, rather than memorize facts and procedures, and learn to appreciate how the data from various subjects and their own experiences are interrelated. Similarly, the major components of the courses must be integrated so that they support and reflect each other in a coherent strategy. Thus, the combination and sequence of concepts presented in the engineering design courses are important. The courses, entitled Engineering Design and Communications I and II, are in their fifth year and are still under constant development and revision in an attempt to optimize course content, improve organization, enhance the students’ design experience, and enhance their teamwork skills.
**Purpose**

The aim of this project is to develop two first-year engineering courses which stimulate student interest in engineering and provide a positive and challenging design experience.

**Variables**

The successes of and ongoing improvements to the course can be attributed to a number of variables. Those which we have found to have the greatest impact on the quality of the courses are as follows:

*Increasing complexity of projects*
Design projects increase in length from short-term (2 weeks) to long-term (full semester) over the year. In the first semester, the first design lab involves a team bridge design competition using Lego (approximately 1.5 hours), with varying constraints and criteria. The following project is 2 weeks long, where students design an egg-holding device with time, material and budget constraints, then test it and write a feasibility report. The final term project is 4-5 weeks long, and involves building a cardboard mock-up of a toboggan as well as a full model in the wood shop, testing, several technical reports and an oral presentation. In the second semester, the design projects are based on real-life problems. In the past, there have been several different projects to choose from each year, with real clients whenever possible. Some groups have even been successful enough to continue to work with their client, develop a business plan and bring their design to market. This year students have been asked to design something to help people with disabilities.

**Course content**
When the design courses were first put into place, they replaced a drafting and a technical writing course. It was difficult to decide what the most important components of these courses were, how to balance the topics, and how many could be integrated into the new “design and communications” courses without overwhelming the students. Over time, the drawing and sketching topics were refined to reflect what we considered most important for helping students visualize objects in 2- and 3-D and to communicate their ideas. However, technical writing instruction has been increased and made more specific in response to the students’ poor general writing skills and lack of background in technical and report writing.

Communications topics include:

<table>
<thead>
<tr>
<th>Drawing</th>
<th>Writing</th>
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<tr>
<td>First semester</td>
<td></td>
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<tr>
<td>• Basic sketching</td>
<td>• Grammar</td>
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<tr>
<td>• Multiviews</td>
<td>• Nouns &amp; pronouns</td>
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<tr>
<td>• Proportioned sketches, construction lines</td>
<td>• Adjectives &amp; adverbs</td>
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<td>• Rules &amp; visualization, dimensions</td>
<td>• Verbs &amp; prepositions</td>
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<td>• Isometric &amp; oblique pictorials</td>
<td>• Conjunction &amp; punctuation</td>
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<tr>
<td>• Isometric drawings</td>
<td>• Technical report format</td>
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The basic design process we teach in class is as follows:

- Identify problem and analyze needs
- Define criteria and constraints
- Generate alternative solutions
- Select best solution
- Optimize solution
- Implement solution

The biggest difficulty we have had in teaching design is to actually get the students to perform the steps of the design process. Typically, they come up with an idea immediately after the problem is presented to them, and then get annoyed because they feel the instructors are wasting their time by forcing them to back up and go through the process. Often, they half-heartedly go through the steps but still design a solution similar to their first idea. It is only at the end of a course when they finally test their design that they finally realize that they did not spend enough time and effort at the beginning of the process. In the past, the second semester, full-term project has involved submitting a proposal halfway through the term, then building a prototype and writing a final report. However, this has often been too rushed and, being novice designers, the students write a proposal without having explored the problem thoroughly. Their final product often ended up being quite different from what they proposed as they built and tested and inevitably made changes in the second half of the semester. Therefore, the entire second semester is now devoted to designing a solution for a given problem, with more time for prototyping and testing, leading up to a proposal and prototype to show proof-of-concept at the end of the semester.

Use of reflection and revision

As design is a topic that is “learned by doing”, it is important for the students not just to “do”, but to reflect on their work and have a chance to improve. Therefore, rather than have them write up to six different types of technical reports (as we did in the first year), we have introduced just a few types of reports and used them for more than one project. In the first semester, for example, students write a feasibility report for their egg-holding device, and then again for their term project. The first few lectures of the second semester involve the instructor guiding a class discussion on the previous semester’s term project and what was done well or could have been done better. At this time, students also fill out a survey that gives them the chance to reflect on how well their team worked and why, their own personality and work style, and what they liked/disliked about the previous course. Revision is also encouraged, for example in an early assignment where groups of students write instructions for building a given Lego mechanism, which are then marked by another group who try to follow the instructions and
give feedback. The groups learn from their peers the importance of accuracy and clarity in writing as well as drawing, then get a chance to revise their instructions before handing them in to the instructor. We believe these activities not only help to improve the students’ performance on subsequent projects, but to increase students’ awareness of the skills they have gained.

**Team evaluations**
The students work individually on regular writing and drawing assignments, but in teams of up to five on all design project-related assignments. With a range of experience and maturity levels among first year students, there are inevitably some teams that encounter problems working together at some time during the semester. Although coached to keep records of problems and to discuss them with the instructor, students often don’t want to “rat” on their peers until things come to a head at the end of the semester. Generally, it is fairly obvious to the instructor when a team is having difficulties, and the instructor can step in to provide advice and coach the group in its teamwork and management skills, or host problem “mini-clinics” with the class. In addition to this, the next best way we have found to address team problems is to implement an interim group evaluation. As a team, students are asked to rate the degree to which each member fulfilled his/her responsibilities in completing the team assignments to date. They are instructed to consider each individual’s level of participation, effort and sense of responsibility, not just his or her academic ability or specific skills. The students must agree on ratings as a team and each must sign the document. The interim evaluation does not affect marks but gives students a chance to address issues before they get out of hand, and gives anyone not pulling their weight adequate warning.

At the end of the semester, students fill out a final team evaluation. This evaluation can affect their marks and they have been aware of this possibility since the beginning of the term. Each team member is evaluated by the group and given a rating based on the percentage of work or effort they contributed to the project. This rating is turned into a multiplication factor by which all of their project-related marks are multiplied. All group members must sign the document. If an agreement can’t be reached, the group must meet with the instructor. Generally, most groups can come to an agreement on their own.

**Organization of class time**
Each week, students spend 1 hour in lecture, 170 minutes in a “long lab”, and 110 minutes in a “short lab”. The same students are grouped together for long and short labs, enabling group work to be performed from week to week. Initially, lecture topics and activities in the labs would change from week to week, depending on what stage of a project we were at (eg. lecture one week on drawing, the next on feasibility reports). While topics and activities would be announced in advance, students (and sometimes instructors) found it difficult to anticipate what to prepare for from one week to the next. Therefore, a strict schedule was implemented where the lecture topics are now solely on design, the short labs are for instruction and individual work on drawing and writing, and the long labs are the “design labs” where students perform design-related activities and work in groups on a project. This structure helps both students and instructors to prepare for classes from week to week.
Interdisciplinary instructor team
In order to provide the best information and instruction for our students, we have employed an interdisciplinary team of experts to teach the design classes. A technical drawing instructor has taught and evaluated the drawing and sketching part of the course, an English instructor the technical writing part of the course, engineers the design component, and a former construction worker and shop teacher has managed the workshop. Having a diversity of instructors can be a benefit for students for a number of reasons. However, due to the fact that we typically have 6 sections of the course each semester, we have had as many as 8 instructors involved at one time, and some of them change from year to year. As many of the topics overlap (for example, what students learn in technical writing and drawing should be implemented in their design reports), it has been difficult to ensure that all students are receiving the same information from all instructors at all times. It has also been difficult to coordinate so many instructors in order to organize the course and agree on course objectives and standards. Therefore, this year we have minimized the instructors to one drawing instructor, one writing instructor, one design instructor and one shop manager for all 6 sections. The students still benefit from the expert backgrounds of the various instructors but receive much more consistent instruction and feedback on their work.

Discussion

The Mount Royal College engineering instructors believe we have two unique first-year courses that are consistent with the needs of our students and the latest engineering design pedagogy. Over five years, we have followed the design process ourselves by analyzing students’ needs and implementing new ideas in an iterative way, in an attempt to optimize course content, improve organization, enhance the students’ design experience, and enhance their teamwork skills.

While we believe the courses have improved substantially in these aspects since their inception, the courses are by no means easy for the students. They are not used to solving problems which have no unique solution, to analyzing and synthesizing data, to recognizing the limitations of an analysis, nor are they used to having to justify their ideas in writing or other means. Working in teams adds another layer of complexity and sometimes frustration to their efforts. It is important to begin to challenge them in these ways as they rarely have been exposed to such tasks in their previous experiences (generally high school but also work in trades or other vocations). We believe that not just design courses but all engineering courses should incorporate active, inductive and cooperative learning techniques in order to prepare our students to become good designers and engineers.

Overall, student ratings of instructors and the courses have increased by at least 20% over this time. However, these ratings were taken from a standard, institutional course evaluation form that asked generic questions such as “Does the instructor communicate course content in ways that help you learn?” and “Are effective examples, illustrations or applications used to clarify concepts?” In order to continue to refine the course in the future, we implemented a new survey at the beginning of the second semester this year, asking questions that were much more specific to teaching and learning design. In addition to encouraging students to reflect on their first semester experience, the survey was designed to better understand student expectations, their
understanding of design concepts, their attitudes about the course/instructors/marking and their awareness of their own skills, strengths and weaknesses. Survey questions include:

- How well did your group function last term? Why?
- How do you want to select your group this term? Why?
- What are your strengths/weaknesses in group work?
- What are the major steps in your design process?
- What are the most important steps, and why?
- What, if anything, have you designed prior to last semester?
- Do you prefer design projects that are highly constrained, not at all constrained, or something in the middle? Why?
- Name and describe something you think is well-designed and why.
- What could be improved about how you were evaluated last term?

Results from the survey will be used to inform yet another iteration of the design process next year.

Acknowledgements

This project was funded in part by Petro-Canada.

Bibliography