AC 2008-707: IMPACT OF PEER-MANAGED PROJECT-BASED LEARNING IN FIRST YEAR ENGINEERING

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Impact of Peer-Managed Project-Based Learning in First Year Engineering

Abstract

This paper presents the outcomes andimpact of a project-based course in first year engineering that was developed to provide an opportunity for students to develop basic engineering skills through experiential learning while encouraging students to maintain the sense ofcuriosity prevalent upon their arrival. An assessment of engineering skill development in the courseof 600 first-year students is discussed, particularly design, communication, and information literacy skills. Student comments about the self-directed experiential nature of the course will also be discussed. Student attitudes and study behaviours, as measured by faculty-wide student surveys using the Lancaster Inventory of Approaches to Learning, are assessed. Finally, thoughts about the overall impact of this learning experience will be presented.

Introduction

Engineering education practice includes a focus on developing engineering skills, in many cases in the form of project-based design courses. Students develop skills like design, communications, measurement and experimentation, data analysis, information literacy, etc. in the process of managing a significant design project. Such project-based courses caninspire curiosity, increase student motivation, and provide students a feel for the activities of practicing engineers.

Ten years ago at Queen's University an initiative was introduced to promote integrated learning in the engineering program, incorporating open-ended design, teamlearning, and professional practice. The approach including construction of new facilities in a building dedicated to student-centred learning, creation of new positions in engineering education and design engineering, and development of new methods of educating engineers[1,2,3]. Part of this push was the development of a new modular first year course, *Practical Engineering Modules*, that sought to broaden students' perception of engineering, inspire curiosity, and develop skills in design, teamwork, and experimentation[4]. This course has continued to undergo changes over the past 10 years.

It consists of two semester-long modules, in which half of the first year engineering students register in each semester. One of the modules focuses ondesign of experimentation, measurement skills, and data analysis and involves laboratory-based work[5] The other module is a semester-long team-based design project, which is the focus of this paper.

In this module students work in teams of 3-5 to solve an open-ended design problem. One of the decisions made early in the development of the course was to use upper year engineering students as project managers. These student were selected for their leadership skills, experience working with people, and engineering design experience. These positions became popular, and attracted top students from across the Faculty of Applied Science.

The project portion of the course has little formally scheduled contact time; rather students work on their own time, guided by short workshops and their project manager. They are expected to spend approximately 5 hours per week working on their projects. The course has no regular lectures, textbooks, or exams.

Project Overview

Three student teams, in sub-teams of 3-5, work on each project, directed by an upper year student serving as a project manager, and a faculty sponsor. For many of the projects, an agency partner is also involved. The project structure is shown pictorially in Figure 1.

One of the most critical roles in these projects is that of the upper year peer managers. Although they are hired to only manage these projects, in practice they often serve as general mentors for incoming students. Their role includes arranging initial meetings, helping the teams create timelines and goals, providing guidance and feedback on oral presentations and written reports, guiding students to resources available at the university, and evaluation of team progress and deliverables.

Approximately 25 third and fourth year engineering students are hired in April for project manager positions in the September-April academic year. Preference is given to those who have demonstrated leadership skills, industrial experience, academic strength, communication skills, and design skills. A significant number also have formal training in design tools and methodologies. At the beginning of the year all project managers are required to hold current workplace safety certification and first aid certification. Their role-specific training consists of a one-morning session covering the objectives of the course, planning, evaluation, running meetings, and available resources.

Each project is overseen by a faculty member who serves as a sponsor and technical mentor. The faculty sponsor also evaluates each team's proposal and final deliverables.

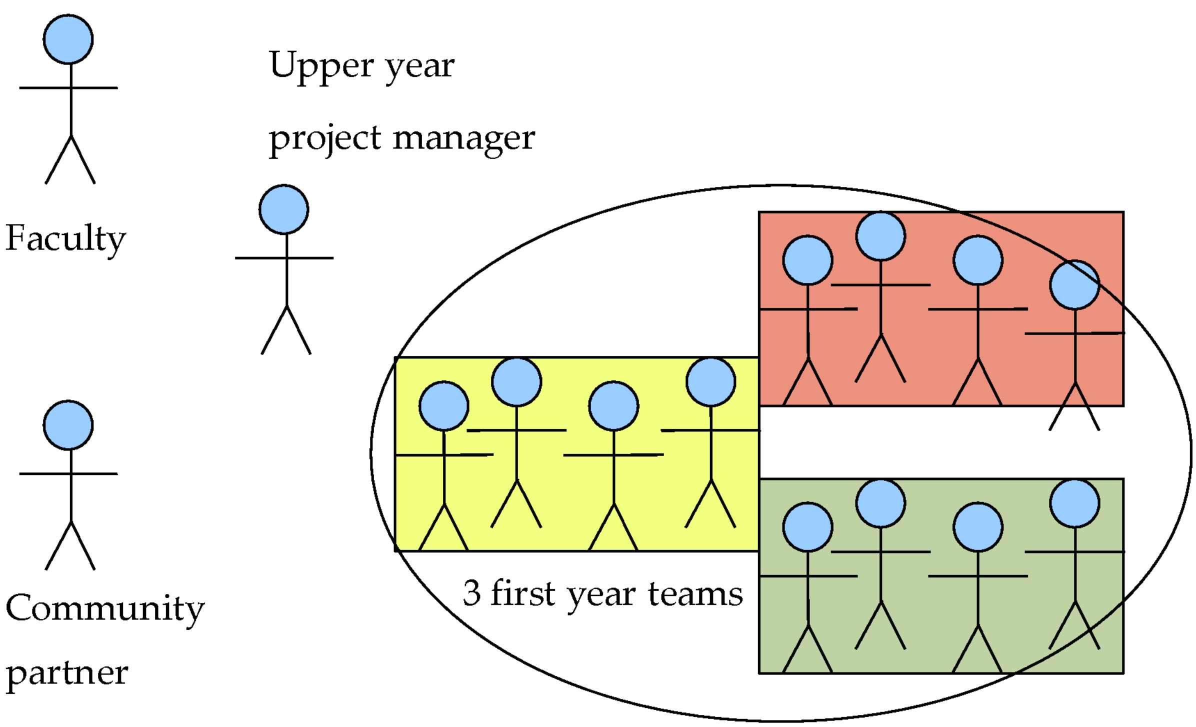

Figure 1: Project team structure.

The course was structured to encourage creativity and exploration, and to provide intrinsic motivation for completing it. Students are given one of four letter grades (A, B, C, or D for failure), and the mark does not count in their overall average. This grading scheme was selected for several reasons: students cannot select their own groups we did not want students trying to maintain scholarships to be affected by less ambitious teammates. The four letter grades reduce the variation in marking between different project managers and faculty sponsors, and allows students the flexibility to create without focused on a right answer in order to achieve high marks. The intention was to provide interesting and motivating projects that the majority of students would be intrinsically motivated to complete. This will be discussed further in the assessment section.

Personnel and Facilities

The course is coordinated by one faculty member who directs curricular development, oversees project development, assesses outcomes of the course, and arranges workshops with other experts. An administrative assistant manages the day-to-day operation of the course, including group assignments, evaluation, communication with students and project managers, etc. The projects are directly managed by the project managers, who provide the bulk of the guidance for the projects. Each project is overseen by a faculty sponsor, who may have also created the project, who evaluates student teams and may provide technical guidance.

The activities are supported by the Integrated Learning Centre which provides many of the specialized facilities necessary to support project-based and team-based learning. There are small group rooms bookable by students (they hold 6 to 10 people), a multimedia presentation room, a design studio, and a prototyping workshop for student use. Specialized e-learning facilities in the Engineering and Science Library are also used.

Many of the projects are proposed by community groups or on-campus agencies, and these groups provide some guidance and constraints for the design teams. Experts in specialized fields, including library science and technical communications, facilitate workshops on a just-in-time basis to provide guidance to teams as they need it.

Workshops

The first workshop is a 1.5 hour guided design challenge offered at the beginning of the semester that introduces a simple design process and emphasizes problem analysis and time management. Students teams work on the design and creation of a prototype needed by a client in a scenario presented to them, but the facilitator pauses their progress several times through the design to ask questions to simulate thought about their progress and plan.

The semester-long design projects require students to research existing solutions and develop an understanding of patents, standards, and regulations as appropriate for their projects. For the past two years the Engineering library has run the second workshop in the third week of the project to introduce students to the library system, showcase electronic resources for locating information, and explain the importance of evaluating information sources. Librarians help students find information appropriate to their project which may include patents, standards, academic literature, texts, and maps.

The third workshop focuses on technical writing and the creation of a final report, and is run by the Technical Communications group which provides most of the instruction on technical writing throughout the Faculty of Applied Science. The student teams provide a draft of their reports to writing tutors, primarily professional writers in the community, three weeks before the conclusion of the project. The writing tutors review the drafts and meet with the student teams to provide feedback. Instruction on the use of word processing and presentation software provided in another course is timed to coincide with the timeline of the project report.

Projects

Approximately half of the student projects are posed by community groups, including local schools, environmental organizations, hospitals, a museum, a housing agency, and on-campus groups. The other half of the projects are proposed by engineering faculty and are generally more academically focused. Two of these are pilot projects that integrate first year teams with upper year teams on a single project. Table 1 lists the projects available in 2007/2008. A discussion on observed differences between agency and faculty-proposed projects in this course has been presented previously.[6]

Assessment of student perceptions and impact

Significant effort has gone into assessing the impact of the course on student attitudes and learning. This has been done using:

- online midterm and final course surveys
- a design skills assessment survey delivered before and after the projects
- an information literacy skill assessment survey delivered before and after the projects
- a faculty-wide survey using the *Lancaster Inventory of Approaches to Learning,* run for the past 13 years

The course surveys and faculty-wide Lancaster Inventory of Approaches to Learning (LIAL) consist of questions for which responses are made on a 5-point Likert scale, where possible responses are *strongly agree/agree/neutral/disagree/strongly disagree*. This results in ordinal data with rank order that can be analyzed for significance using statistical nonparametric tests like the Wilcoxon signed-rank test (used to examine changes in a sample of student responses at two points in time), the Wilcoxon-Mann-Whitney test (used to compare two independent samples of responses), and the Kruskal-Wallis test (used to examine variance in three or more independent samples).

Final course survey

At the end of the projects all students were asked, by e-mail, to complete on online survey. Table 2 lists the items on the final course survey run in 2007/2008, though it is quite similar to the survey in the previous year. The responses to Questions 1 through 20 are made on 5-point Likert scales, Questions 21 and 22 are a 5 point ranking (1 being poor, 5 being excellent), and Questions 23 and 24 have open text fields. There were 181 responses to the survey in the 2006/2007 academic year out of approximately 560 students, and 64 responses in the fall semester of 2007 out of approximately 270 students. The course survey has changed slightly over the past two years, but most responses to items can be compared over the past two years.

Table 1: Projects offered in the 2007/2008 academic year.

Faculty Proposed	***Agency Proposed***
• Hydraulic Engineering: Design of a Stilling Basin • Reprocessing of an Existing Landfill Site to Reclaim Volume and Recycle Materials • Bicycle Illumination System • Design and Construction of a Manually Operated Scratch Tester • Flawed Plastics • Oral Biofilms: How Good is Your Dental Hygiene? • The Knee Bone's Connected to the..The One-Legged Acrobot • Greenamps: An Electrical Power Monitor (joint project with fourth year electrical engineering capstone course) • Multi-Purpose Playground Design • Design, Implementation and Test of an Optical Communication System • Design and Test of an Assistive Seat Belt Device • PEC Generation Centre (joint project with third year multidisciplinary design course) • Design, Development and Study of a Solar-Powered Cordless Drill • Simulated Strengthening of Circular Columns in Bridges	• Integrated Learning Centre: Green Wall Exploration • Integrated Learning Centre: Power Consumption on Campus • Design of a Compact Can-Crusher for Habitat for Humanity • Integrated Learning Centre: Green Roof Aeration and Watering System • Alternative Power Sources at Hotel Dieu Hospital • Anaesthetic Gas Recovery at Hotel Dieu Hospital • Green Roof Feasibility at Hotel Dieu Hospital • Waste Reduction at Hotel Dieu Hospital • Water Conservation in Hotel Dieu Hospital • Living Energy Lab: Optimization of Awning Angle Over Windows • Living Energy Lab: Water Purification for Developing Countries • Living Energy Lab: Eco-Friendly Insulation • Living Energy Lab: National Techology Youth Leadership Conference Modules • Living Energy Lab: Design of a Retrofit Dual Flush Toilet System • Living Energy Lab: Design of a Delayed Garden Watering System • Child Seat for an Arm Ergometer at Hotel Dieu Hospital • Educational Water Table Design for the Pump House Steam Museum • Development of a Multipurpose Trail and Interpretive Centre Near the Great Cataraqui Marsh • Community Outreach: Design of a System for Tracking Student Marks

Table 2: Course survey items in the 2007/2008 academic year, most of which are identical to questions in the 2006/2007 academic year.. The available responses to most are ***strongly agree, agree, neutral, disagree, strongly disagree****.*

1. My group communicated with an expert/client/faculty regularly for guidance. 2. My project helped me learn how to communicate with non-engineers. 3. My project introduced me to real-world engineering issues 4. My project was interesting 5. I found the project too difficult. 6. The project encouraged our group to be creative. 7. This course broadened my perceptions about the skills needed by engineers. 8. We were given the necessary instruction about safety in our lab/workspace. 9. Our team's Project Manager was a valuable source of guidance, information, and resources. 10. I found that it was important to work as a team to complete this project. 11. Our team's Faculty Sponsor was a valuable resource. 12. My Project Manager showed genuine concern and interest in the team members.	13. I feel more comfortable doing engineering design as a result of this project. 14. I feel more comfortable doing oral presentations now than at the beginning of the semester. 15. I did not learn much during the design project. 16. The engineering communications tutors were helpful. 17. The library information sessions helped me learn how to find and evaluate information. 18. I was motivated to do well on this project because of interest. 19. This project helped me feel more comfortable working in a team. 20. I learnt a lot about creating engineering documents in this course. 21. Overall I rate my team's Project Manager as: 22. Overall I rate the design project and my experience as: 23. What was your overall impression of APSC-100 Module 3? 24. How could APSC-100 Module 3be improved overall?

Design and information literacy skill assessment

Since the project is student-directed and open-ended, assessment of student development is quite different than traditional instructor-directed courses. Assessment of design skill development, one of the major objectives of the course, is quite challenging particularly when working with a large number of students. Light et al. presented a paper-based survey as part of the Academic Pathways Study, a multi-institutional longitudinal study run out of the Center for the Advancement of Engineering Education[7]. In this survey, students were asked to select the types of information, from a provided list, that they would most likely need as they worked on their design. This provides for relatively simple comparison between students, but provides prompts to students and somewhat constrains their ideas.

For this course a more open-ended assessment was designed. Students were asked to indicate on a 8.5x11 inch paper the general steps they would follow to solve a design problem, which they could select from a list of three scenarios. This survey was given as a pre-test at the beginning of the course, and a post-test at the end, though with different design scenarios. One of the design surveys is shown in Figure 2.

We are asking you to complete this brief design skill assessment at the beginning your project, and a similar one at the end. This will NOT be part of your mark; rather we would like to assess changes in your engineering skills. We are asking for your student number only so we can track changes between the pre-project assessment and post-project assessment.

Instructions: You should select one scenario from the list below, and respond to the question below based on that.

Pre-Schooler Tricycle

You are an engineer at Engineers "R" Us, Inc., a company that designs and markets bicycles and tricycles. You are part of a team of engineers responsible to design a tricycle suitable for use by a pre-school aged child (ages 1-3).

Desk for Vision Impaired

You are an engineer at Engineers "R" Us, Inc., a company that designs and markets office equipment. You are part of a team responsible to design a desk for someone who is vision impaired.

Payphone

You are an engineer at Gong, Inc., a startup company in the telecommunications market. You are part of a team of engineers asked to design the interface of a new payphone that will compete with the current Bell payphones.

1. Circle your selected scenario.
2. Describe, in point form on the back of this page, the general steps you would take to ensure a successful design for your selected scenario. Note that **you do not need to create a design, sketch, etc.** We simply want to you indicate the general process you would follow.

Figure 2: Design survey run before and after the project, with only the scenarios changed.

A similar survey was run to assess the development of skills in information literacy. A survey was given to half of the students selected randomly from the incoming class. This survey is very similar to the design assessment survey but asks students indicate the type of information they would use in the process, rather than asking them to describe the steps they would take to complete the project.

Lancaster Inventory of Approaches to Learning

Since 1995, at the beginning of the revision of the engineering program, all engineering students have been asked to complete an online version of the Lancaster Inventory of Approaches to Learning (LIAL)[8] three times throughout the program: the first time upon arrival in September of their first year, the second time in April after completion of the first year, and in April after completion of their final year.

The survey consists of 63 items that give scores for motivation and study methods. The items are divided into 16 sub-scales[9]:

Deep Approach	Strategic Approach
Relating Ideas	Disorganized Study Methods
Use of Evidence	Negative Attitudes to Studying
Intrinsic Motivation	Achievement Motivation
Surface Approach	Comprehension Learning
Syllabus-Boundedness	Globetrotting
Fear of Failure	Operation Learning
Extrinsic Motivation	Comprehension

Principal factor analysis on the sub-scales in the original study by Ramsden and Entwistle identified factors they identified with particular academic orientations that included were Meaning Orientation, Reproducing, Non-Academic, Strategic, Comprehension, and Operation.[9] This survey has provided a large amount of data in the Faculty of Applied Science at Queen's University (N=10078 responses) over 13 years on self-reported student attitudes and behaviour. Students were asked to respond to each question using a five-point Likert scale.

Of most significance for this discussion are the first four sub-scales. The meaning of these scales are as follows:

- Deep Approach sub-scale contains four questions indicates students' preference for actively questioning during their learning
- Relating Ideas sub-scale contains four questions and indicates students' preference for relating ideas to other parts of the course or curriculum
- Use of Evidence sub-scale contains four questions and reflects students' preference for relating evidence to conclusions
- Intrinsic motivation sub-scale contains four questions and reflects students' interest in learning for its own sake

Results and Analysis

Peer management

In the final course surveys the upper year project managers have been ranked very highly by students and question 21 (Q21), which asks for an overall rating of the project manger (PM), has been the most positive response on the survey. In the past three academic years, 83% (N=389) gave their PM a 4 or 5 out of 5 in overall ranking. In the fall 2007 survey (N=64) even those who ranked their project low (a 1 or 2 out of 5) were more likely to give their PM a 4 or 5 (9/64 students) than a 1 or 2 (1/64 responses). Interestingly in fall 2007 only 1 student ranked their project manger a 1 or 2 out of 5, and that PM was given a 5 by the only other person who ranked that same project manager. In the past two years 76% of respondents felt that their project manager was a valuable source of guidance, information, and resources (Q9).

The overall rating of project managers (Q21) was significantly higher in 2007 (94% received a 4 or 5) than the number who found their PM to be a valuable source of guidance, information, and resources (Q9). Although it is not possible to say definitively why this is the case, it may be related to the perceived value of the project managers as sources of advice for the program in general, rather than in only the particular project. One of the comments reflected this:

"I enjoyed the project. It was helpful to get to know an upper year student for help not only in APSC 100, but for advice in other courses."

Attitudes

Student attitudes toward the design project, and engineering in general, are reflected in both the final course survey and the LIAL. In Fall 2007, 70% thought that the project introduced them to real-world engineering issues (Q3), and 68% said that their perceptions of engineering were broadened by the course (Q7). One concern often associated with student-directed learning is the question of how much students benefit. In the past two years, only 14% (N=245) of students indicated that they did not learn much (Q15). Given that the first year students interact with instructors only during the three workshops, and that the workshops are generally ranked quite low (as will be discussed below), it seems that students perceive that they are learning independently.

In fall 2007 60% of students in fall 2007 said that they felt more comfortable doing engineering design as a result of the project (Q13). Approximately 57% said that they felt more comfortable working on a team as a result of the project (Q19).

As discussed above, the course grading scheme was structured to encourage students to learn out of interest, allowing them to approach a problem without concern for marks. In fall 2007 40% said they were motivated in their project work out of interest, indicating that further work should be done in developing interesting projects, and helping students to perceive value in the course.

Several students commented that they found it difficult to adapt to the open-ended and student-directed nature of the projects; some comments included:

- "Our project was too vague and broad"
- "Scrap the project until upper years; some first-years haven't gotten used to freedom, and chose to do no work"

- “I think more structure is needed to encourage students to work to their full potential.”

While there may be legitimate concerns related to the management of some projects, this also likely reflects student preference, established in most of their prior formal education, for closed-ended problems with single correct answers. This preference was one of the reasons for the creation of this course.

The data from the faculty-wide LIAL was used to examine changes in student attitudes toward learning in the first year program. Of the 10078 students who responded over the past twelve years, N=2532 students completed the survey at the beginning and end of their first year (September and April, respectively). The data in the 63 items was used to calculate the 16 scales. The Kruskal-Wallis rank sum test was used to determine statistically significant changes over the past twelve years for the 16 sub-scales. The p-values for the sub-scales is shown in Figure 3; for a 95% confidence interval the p-values less than 0.05 indicate the sub-scales where statistically significant changes have occurred.

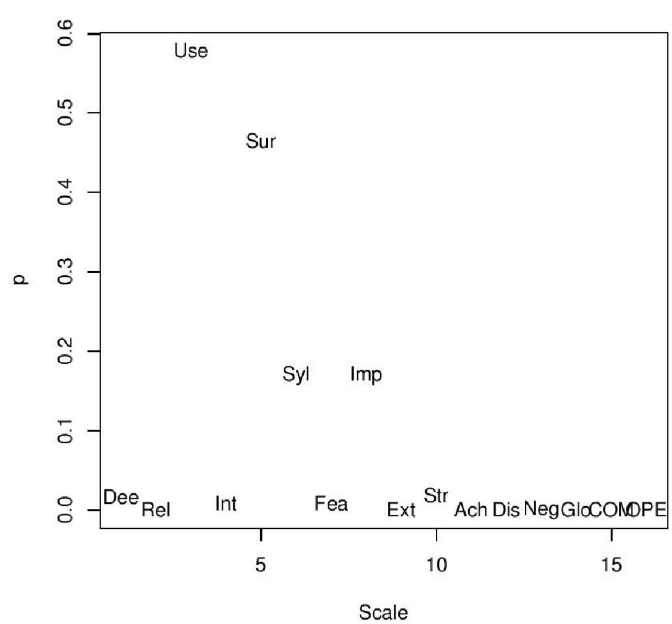

Figure 3: P-value of Kruskal-Wallis rank sum test indicating significance of change in the sub-scdes.

Using this result, the individual changes of three of the sub-scales with significant changes (Deep approach, Relating ideas, and Intrinsic motivation, indicated by “Dee”, “Rel”, and “Int” in Figure 3, respectively) were assessed. The changes between each student's response in September and December was assessed for each year; for example, the histogram of the changes in the *Relating ideas* subscale for students in the class of 2010 is shown in Figure 4. The majority of the students (approximately 100) had no change in this sub-scale, with approximately 20 going up by one point (out of five), and approximately 10 going down by a point.

Finally, the changes of all students in each year was summed over each sub-scale to allow overall changes to be plotted. Figures 5, 6, and 7 show the sums on the Deep approach, Relating ideas, and Intrinsic motivation sub-scales. As can be seen, the change in most years in most of the sub-scales go the "wrong" direction – i.e. the change on the sub-scales is negative, indicating students are moving away from deep learning almost every year. However, the three sub-scales have been moving up in the past four years. It is not possible to determine the contribution of the design projects to this change, but it is encouraging that the students are moving toward more deep learning, relating multiple, ideas and intrinsic motivation.

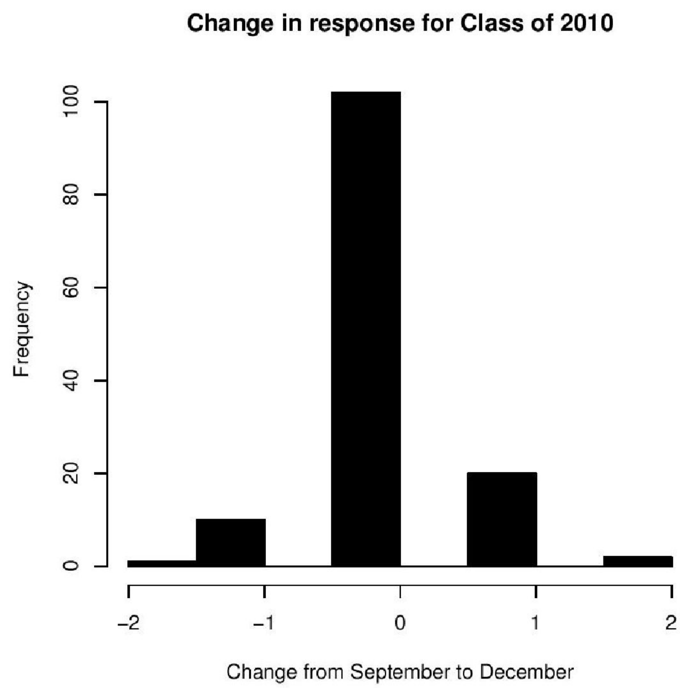

Figure 4: Frequency of change in Relating Ideas scale from September to April of first year for the class of 2010.

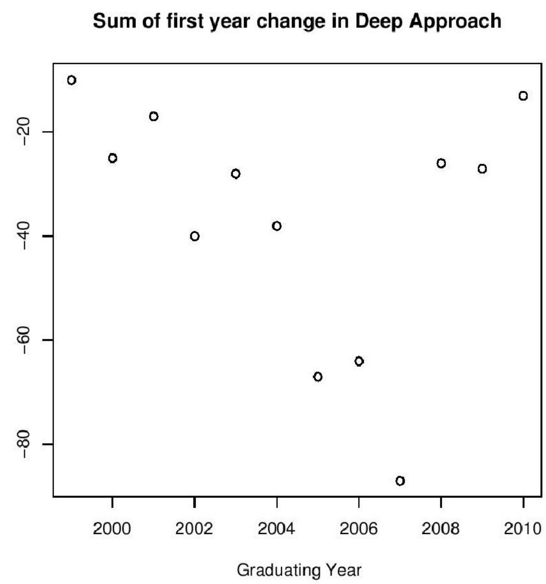

Figure 5: Sum of change in first year responses to Deep Approach sub-scale (N=2532)

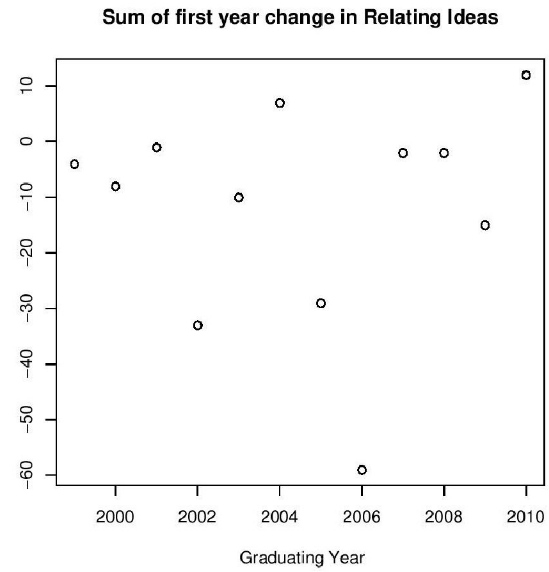

Figure 6: Sum of change in first year response to Relating Ideas sub-scale (N=2532)

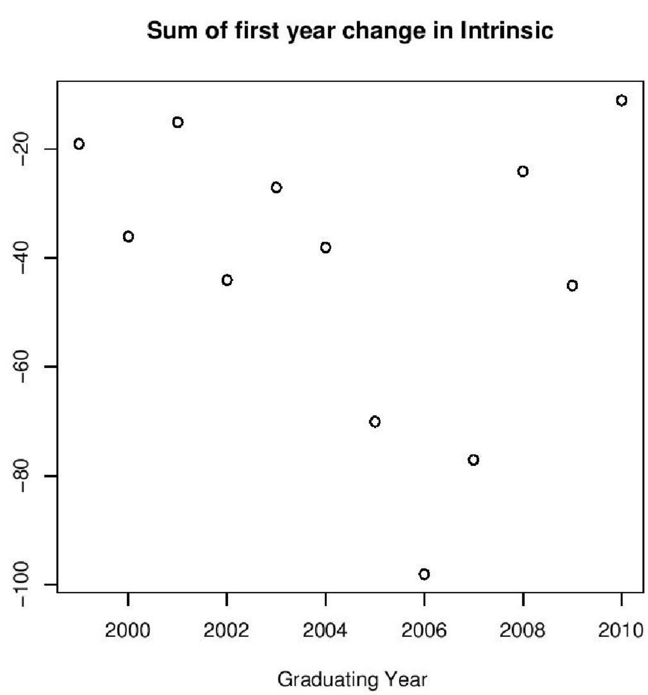

Figure 7: Change in first year response to Intrinsic motivation sub-scale (N=2532).

Workshops

In the past two years the workshops have been the least popular aspect of the course; 39% (N=241) of the students felt that meeting with writing tutors was helpful, and 29% (N=243) felt that the library sessions helped them learn how to find information. This may partly reflect resentment of the fact that these are the only mandatory meeting times in the project.

We are currently piloting three smaller workshops for information literacy: we introduce general library resources and tools in the existing course overview lecture, then student teams meet with a librarian in week 3 to help them locate information related to their project, and then meet again with teams in week 10 (when they meet with the Technical Communications tutors) to help synthesize, evaluate, and properly cite their information.

Design

The student responses to the design survey were assessed using two different rubrics. In the first method ("Quantitative"), students were given up to 12 marks for listing appropriate steps in approaching their design scenario (e.g. problem definition, information gathering appropriate to the scenario, establishment of problem constraints, etc.). In the second method ("Qualitative"), students were ranked at one of six levels based on an assessment of the overall process, e.g. a level 6 required:

> **thorough description of process with details provided**, encompassing all necessary activities (as listed in quantitative assessment list above), including how a step would be performed. This might typify the response of top students in an upper year design methodology course, and **include mention of tools and methodologies**

The rubric was developed to allow comparison of design skills in first year students before and after this project with upper year students in design courses. The highest level among the first year students was a 4, which required:

> description of all major steps in overall process **with specific details provided appropriate to the problem at all stages of design process**. This might typify the response of top first year students at the end of the course

The Wilcox signed-rank test was used to compare the pre/post performance of the sample of the students (N=45 for the pre-test, and N=76 for the post-test), since the grades are better regarded ordinal ranked data than interval data. On the Quantitative rubric, the variation in pre/post data is not statistically significant (p=0.3066, two-tailed). However, on the Qualitative rubric there is a significant increase in results (p=0.0033, single-tailed).

This is a very interesting result. When graded only on their ability to list major steps in a design process, there is no significant change in ability. Students are somewhat familiar with a design process at the beginning of the course (probably through discussion with their project manager at the first meeting), and are able to list idealized steps. However, if students are assessed on their ability to apply a design process to a particular application, there is a significant improvement by the end of the project. It seems that students are developing a deeper understanding of how to apply the design process to a given problem.

Technical Communications

In 2006-2007 40% of the students felt that meeting with writing tutors was helpful, and 34% in fall 2007. 46% felt more comfortable doing oral presentations after the project in both 2006-2007 and fall 2007. However, 66% in 2006-2007 indicated that they learnt a lot about creating engineering documents and 63% in fall 2007.

Conclusions

Overall, the data indicates that the undergraduate project managers are highly valued by first yea students, for their assistance directly related to the project as well as general mentors. Upper year project managers with internship experience and design experience, who have also completed a first year design projects themselves, provide significant service to first year students.

Over the past four years, first year student responses to the Approaches to Studying Inventory have moved in a statistically significant manner in scales of deep approach to learning, relating ideas, and intrinsic motivation. The contribution of this project to the shift cannot be determined, but the student responses are encouraging. A pilot project to assess student understanding of design indicates that these projects are helping students to develop a deeper understanding of how to work on an open-ended design problem.

The just-in-time workshops, used to develop design, information literacy, and technical communication skills, are the lowest rated aspects of the course. We will be working to reassess the structure of the workshops. However, the design skill assessment indicates that students are developing an understanding of a design process, and the ability to apply it. Since the students indicate they are learning during the course of the project but interact with instructors relatively infrequently, it seems that students perceive that they are learning independently.

The course appears to be partly fulfilling its role of broadening students' perceptions of engineering and developing professional skills. Although overall the first year university experience has tended to drive students toward superficial learning, the results over the past four years are trending in a more positive direction.

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