AC 2011-1747: COMPARISON OF ENGINEERING STUDENT SELF-CONFIDENCE AT TWO UNIVERSITIES

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Comparison of Engineering Student Self-Confidence at Two Universities

Introduction

An engineering degree program has been maintained in Halifax, Nova Scotia, Canada, in one form or another, since 1880. Over the years, the program has undergone many changes. Changes in location, in duration, in funding method, numerous changes in institution, and of course changes in pedagogy have all been the subject of heated debate over the years. Ultimately, providing the best training of engineers to serve society has been the non-negotiable aim of all. Canadian engineering schools are now in a period of change, and the experience at *Dalhousie University* is not uncommon. In response to new Canadian standards in accreditation[1], the current degree program is being updated.

Changes that are being implemented are more significant than simply re-arranging course content through the curriculum, or adding and dropping subject matter. The new accreditation standards, and the demands of our student's future employers, are driving us to consider different pedagogical models than our faculty have used in the past. The new program will employ more project-based learning (PBL) to deliver professional content, particularly for design courses.

Research in engineering education shows that PBL is a better model for teaching students professionalism and design.[2,3,4] Despite the substantial body of research into the PBL methods, many engineering faculty continue to come to the model reluctantly. In an effort to give more weight to the benefits of PBL teaching within the *Dalhousie University* experience, *Dalhousie University* is eager to assess and evaluate the impact of PBL additions to the curriculum..

Motivated by new accreditation rules that will take effect in 2012, the first group of students entering *Dalhousie University* engineering program will encounter a core PBL design course in each semester of their first two years, as well as a capstone design project in their final year. Thus, we are moving from a “bookend” design experience—having PBL courses in the first and final years of the program—to a three-year PBL design curriculum.. The 2010 incoming class is the first cohort in the new program, but their experience before January 2011 is predominantly the traditional pedagogical model of previous years. This paper describes the first step in a

project to assess the impact of incoming changes to the student experience by looking specifically at the student's own opinions of their skills and competence.

The *Dalhousie University* bookend curriculum experience is not unique. Several universities and colleges only offer PBL courses in the first and last year of the curriculum. At the *University of Colorado at Boulder*[9] the bookend curriculum was found to be a detriment to mechanical engineering students in the following categories: *Engineering as a Career, Engineering Methods, Design Skills, Communication Skills,* and *Teamwork Skills.* The work described in this paper explores a comparison between research carried out at the *University of Colorado at Boulder*[9] and the recent results from a survey of the *Dalhousie University* engineering population.

Comparing Design at Dalhousie with University of Colorado at Boulder

In many engineering programs, the implementation of PBL has resulted in students encountering a comprehensive design project in one first-year introductory course, and then waiting until a senior year capstone design courses for the next comprehensive design project.[5] In between these courses, an overwhelming number are still taught in a traditional lecture-assignment-exam format, referred to here as "Lecture-Based Learning" (LBL). While many programs adopt active learning models in the classroom, so students may not see strict "lectures", the issue at hand is the student engagement with the content via "project" motivation versus engagement directed by teaching staff. Programs with design projects at beginning and end only are known as "Bookend" design curricula. Presently, the *Dalhousie University* curriculum is substantially a "bookend" type program, as is that of *University of Colorado at Boulder*.

The engineering degree programs at the two Universities bear very strong resemblance to each other. At *Dalhousie University,* students in all disciplines of engineering are required to take a first-year, first semester course "Engineering Design and Graphics". The course has a significant design project component, but it is not entirely a PBL course. The existing course spends about half of the time on a group project, and half of the course in graphical concepts and

drafting. All of the other courses for first year students are traditional LBL models, and many are taught as service courses by other faculties than engineering.

University of Colorado at Boulder Mechanical engineering students, similarly, are required to take a First-Year Engineering Projects course in their second semester. While this course has a stronger "project" emphasis than its counterpart at *Dalhousie University*, both aim to give students the experience of carrying through a significant design project in a team environment. Similar to *Dalhousie University*, most of the other courses in the second and third year of the mechanical engineering curriculum are LBL models.

Prior to the implementation of the new curriculum in 2010 at *Dalhousie University*, only Mechanical engineering students were required to take a second-year project based course. In the *Dalhousie University* system, Mechanical students make up fewer than 20% of the total, so this design experience is not one that is common to the current student population.

Thus, after 3 years of primarily LBL instruction, all engineering students at *Dalhousie University* must carry out a full-year capstone design project in their final year. Students at *University of Colorado at Boulder* have a similar capstone design project experience. Prior to January 2010, the common student experience at both universities was a "bookend" design education.

Study Objectives

It was observed by one of the authors (Dr. Kotys-Schwartz) that students in a Bookend program of Mechanical Engineering in the *University of Colorado at Boulder* suffer a significant loss of self-confidence and enthusiasm in their chosen profession through the middle years of the mechanical engineering program[6]. The students' capstone projects only help to recover some of their self-esteem and enthusiasm. Between 2003-2010, Dr. Kotys-Schwartz administered student surveys at *University of Colorado at Boulder* to assess the attitudes of their students in the following categories: *Engineering as a Career*, *Engineering Methods*, *Design Skills*, *Communication Skills*, and *Teamwork Skills*. The results were striking. As expected, the results

showed that first year students surveyed before entering the First-Year Projects class had a low opinion of their skills and abilities to practice engineering, and this improved statistically after their first semester design courses were completed. By the beginning of their fourth-year, however, the student's self-confidence in their own abilities had been largely eroded, in some cases lower than it had been before they started the First-Year Projects in year one. The student confidence in their skills improved when students completed their senior year courses, including their PBL design capstone course. [6]

The objective of this research is to measure student self-confidence at *Dalhousie University* before the new PBL educational model is phased-in over the next four years. The results are compared with research at *University of Colorado at Boulder* to help detect differences attributable to the different levels of PBL experience in the respective programs.

Methodology

The study was conducted at *Dalhousie University* using a modified version of the survey implemented at the *University of Colorado at Boulder* (between 2003 and 2010), and administered on-line with the in-house Opinio software. Students were sent a series of three invitational emails from the survey engine. The first email (sent on Wednesday January 12, 2011 during a winter storm when the campus had been closed) invited them to participate in the study and included a unique link ID to the survey page. The subsequent email reminders were sent on the following Saturday afternoon and Monday afternoon. The study was closed on the following Wednesday, January 19, 2011.

The list of registered students was uploaded to Opinio by the Associate Dean ensuring that all the current students received an invitation. Since each invitee was given a unique ID for their response, the Opinio software ensured that only *bona-fide* students were able to respond, and each student had only one opportunity to complete the survey. The study had been vetted through the research ethics board of *Dalhousie University* prior to survey administration.

The survey consisted of eleven questions that were consistent with survey questions administered to University of Colorado students. The first four questions were for housekeeping, asking for agreement with the consent form, their entering year, gender, and student ID# (for the purpose of a prize draw). The remaining questions were grouped so as to have no general theme from student's perspective, but to provide efficient use of page space.

Each question contained an array of 6-10 statements. Students were asked to select their level of confidence with each of the statements. A Likert-type scale was used for student confidence ratings, from Highly Confident (5), Confident (4), Neutral (3), Less Confident (2), Not Confident (1). Three students were asked before the study was made "live" to pilot the survey. They reported it took 10-15 minutes to complete the survey and gave valuable feedback on the format. As students completed the survey, data was downloaded to a spreadsheet program by the researchers for analysis.

The statements had been designed to test the student's attitudes of their capabilities in 5 different categories. In keeping with the research performed at the *University of Colorado at Boulder*[7] the categories were:

- *Engineering as a career:* knowledge of the different types of engineering careers and the societal impacts of engineering,
- *Engineering Methods:* engineering related software skills and manufacturing skills,
- *Design Skills:* implementation of the design loop and designing within context,
- *Communication skills*: oral and written technical communication,
- *Teamwork Skills:* conflict resolution, group cohesion and work quality.

The random grouping of statements was developed to ensure that students in the survey did not simply check down the rows of the study without considering the statements. In some questions, wording was changed for the Dalhousie survey to reflect slight context or content differences. Questions that referred to particular software, for example, were modified to be more relevant to the Dalhousie program. An example of the statements is shown in Table 1 for the "Teamwork skills" category. The first column of the table indicates the question number. Statements were interspersed with those from other assessment categories. The statements were skill-specific, and

require students to identify their strengths in definite areas, rather than general expressions of capability.

For contrast to the specific statements, the final question in the survey gave students a list of one-word descriptors and asked them to "Please rate how well prepared you are to incorporate each of the following items while practising as an engineer:" The word list included "Creativity", "Data Analysis", "Design", and "Engineering Analysis".

Table 1: Teamwork related statements

Question	
6 c	I am able to work with people who have a style of work different from my own
6 f	I work cohesively with a group of people toward a common goal
7 b	I am comfortable asking my team members for help
7 f	I am skilled at keeping team members on track to meet project milestones
7 h	I bring to my team the relevant technical background to accomplish a long-term design project
7 I	I am good at listening to other people's ideas
9 a	I am skilled at not letting my own problems get in the way of a team project
9 f	I bring to my team the appropriate hands-on experience to accomplish a long-term project
9 j	I understand how to effectively organize and conduct a meeting
10 b	I bring to my team the necessary teamwork skills to work collaboratively

Results

There were 1135 invitations emailed to *Dalhousie University* students from the Dean of Engineering. The study population represents all students currently enrolled in engineering courses at *Dalhousie University* in all 4 years of the program. The 153 students presently on co-op work placements are included in this number, but were sent invitations 2 days later than the on-campus population. The largest response rate was from the second year students (57%), and the smallest response rate came from the third year students (18%). The majority of the co-op students are in the 3rd year cohort, which may partially explain the low response rate from the 3rd year class. A full summary of response rates is shown in Table 2.

Table 2: Response Rate to Survey: January 12-18, 2011			
Cohort	Responses	Invitations	Response Rate
1st year	130	308	42%
2nd year	130	229	57%
3rd year	66	374	18%
4th year	75	224	34%
Totals	401	1135	36.00%

Figure 1 shows the distribution of responses to a single statement, in this case the statement 8a "*I know which engineering discipline I wish to pursue*". In the response to this single statement, there were 16% of first year students who answered with neutral or less confidence. In the higher years, only 6% of students in each cohort were still neutral or less confident. For this question, there was much more to be seen in the two higher confidence categories. In particular, the shape of the distribution appears to indicate that students from 3rd to 4th year converting from a level of "High" to "Very High" confidence. The result is surprising in the *Dalhousie University* context because students in the second year must select their discipline, and they proceed into separate discipline-specific programs in their 3rd year. The survey suggests that only half of the students in a discipline are highly confident they want to be there, even while they have committed to the specialized program of study.

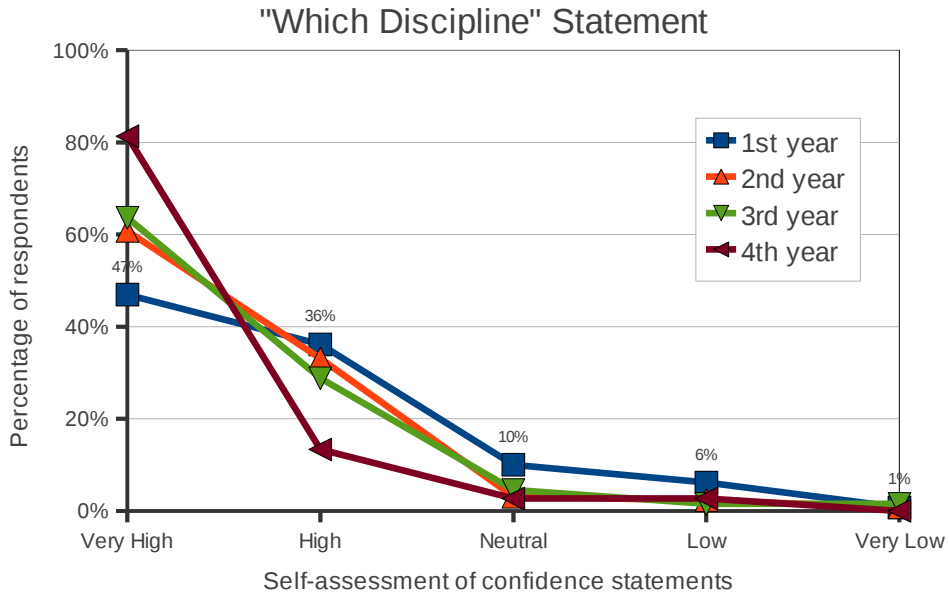

Figure 1: The data plotted shows the distribution of student responses to a single statement "I know which engineering discipline I wish to pursue"

The example of Figure 1 was representative of responses to many of the individual statements. Students typically ranked their confidence in the statements very highly, so that the most interesting details of the survey results can be found in the transition between the two highest rankings. While some faculty may scoff at students assessment of their own skills, it is important to recognize that the value in the survey is not in finding an accurate assessment of student capabilities, but in understanding the student's own sense of their preparedness. As was pointed out in the earlier work,[2] an independent assessment of student capabilities might be a useful complement to the student self-confidence assessment.

Figure 2 shows the response to the statement "I am a skilled technical writer." This particular skill is one that we know is taught throughout the curriculum, including a required course -*Technical Writing*. Despite the clear effort through the program to teach students to be better technical writers, Figure 2 shows that the students themselves have the same low confidence in their skills in 4th year as they had in 1st year. Presumably, the 3rd and 4th year students must have

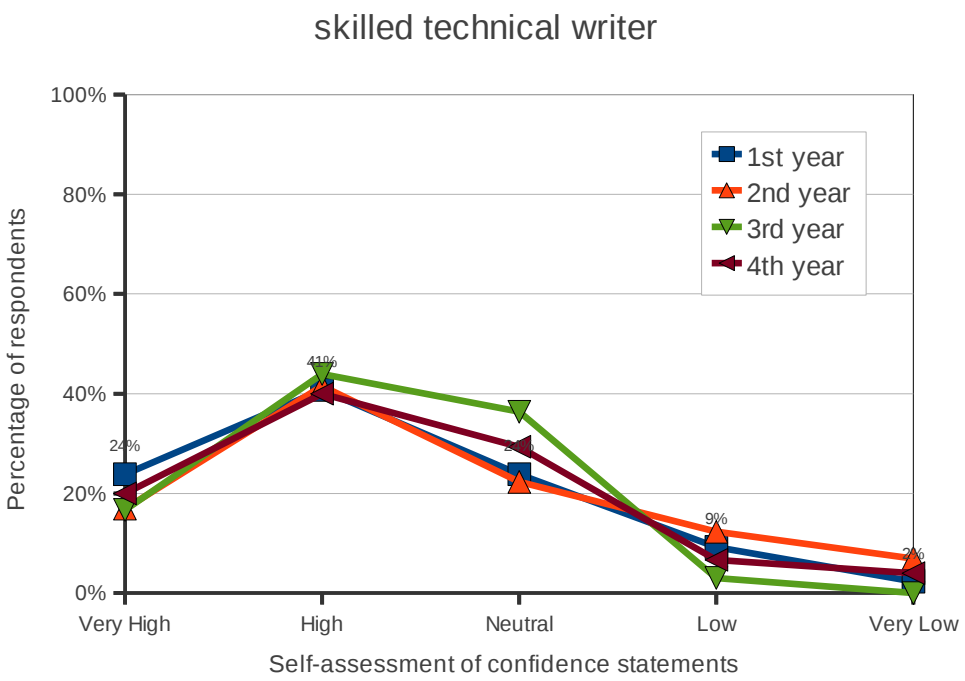

Figure 2: The plot shows the response distribution to the statement "I am a skilled technical writer". The absolute rankings by students was noticeably lower than in most other statements, despite the fact that the student population is required to take a series of "writing" courses throughout their 4 years.

passed their technical writing courses, and were continuing to succeed in courses that demand lab reports and project reports. Despite their proven success in technical writing, their collective self-image appears to be of students who are not confident of their writing ability.

Figure 3 illustrates the responses to an average value of all 6 statements in the survey expressing confidence in "engineering as a career". The summing of responses to several statements allows us to report averages from each cohort that give an estimate of the general movement of student opinion, rather than focussing on the details of each statement as illustrated in the examples of figures 1 and 2. Turning to the average classifications, in Figure 3, we can see that 20% of respondents were neutral in their confidence of their career choice, and only 26% were highly confident. By 4th year, more than 40% of respondents were confident in the statements reflecting career choice, and those neutral dropped to only 15% of the respondents. Thus, the notion that students know more about engineering as a career choice by their final year in the degree program are seen in the average survey results. The next step in this research project will be to investigate the statistical significance between classes (1st year through 4th year) at each confidence level.

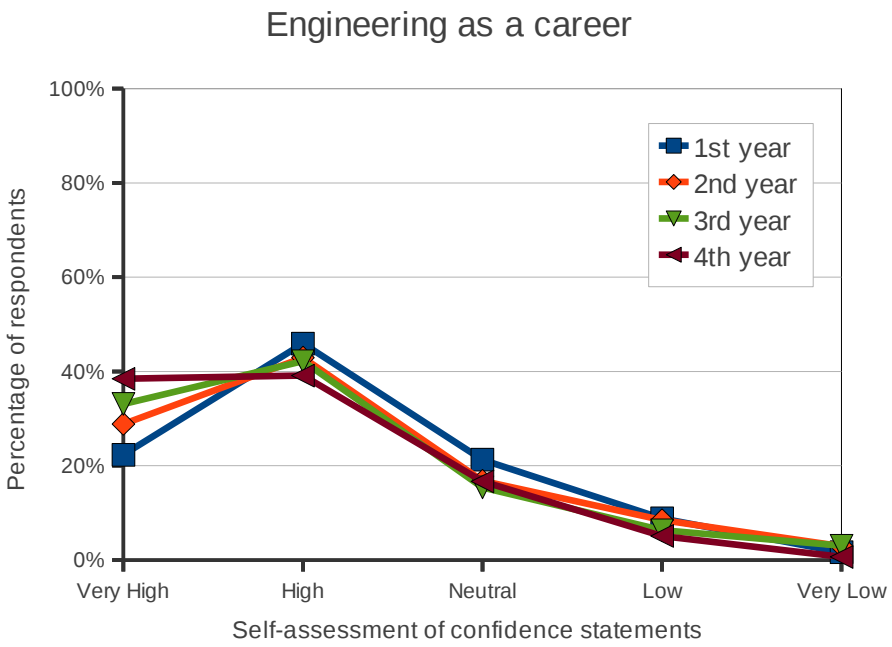

Figure 3: The figure shows the combined responses to a suite of 6 statements related to student knowledge of careers in engineering

Figures 4-8 show the mean value of responses to each of the five classification categories. The data is plotted with the horizontal axis from the beginning of university to the final semester. On this axis, the survey results from *Dalhousie University* were collected halfway through the students first-year, second-year, third-year and fourth-year experience. Data from the previous study carried out at *University of Colorado at Boulder* is also plotted on these axes[6]. We have adjusted the timing of the *University of Colorado at Boulder* results to the times corresponding in the *Dalhousie University* program that reflect the similar contact with PBL design courses. Thus, since *Dalhousie University's* design course in first year occurs in the first semester, we have shown the pre- and post design results from the *University of Colorado at Boulder*[6] as if they were at times 0 and 0.5 years. The corresponding cohort of *Dalhousie University* students were surveyed after their design course, but we have no survey data from the beginning of the course. Likewise, the 4th year class at *Dalhousie University* was surveyed halfway through their year-long senior design projects, while the *University of Colorado at Boulder* data reflects surveys at the beginning and end of their senior capstone design projects.

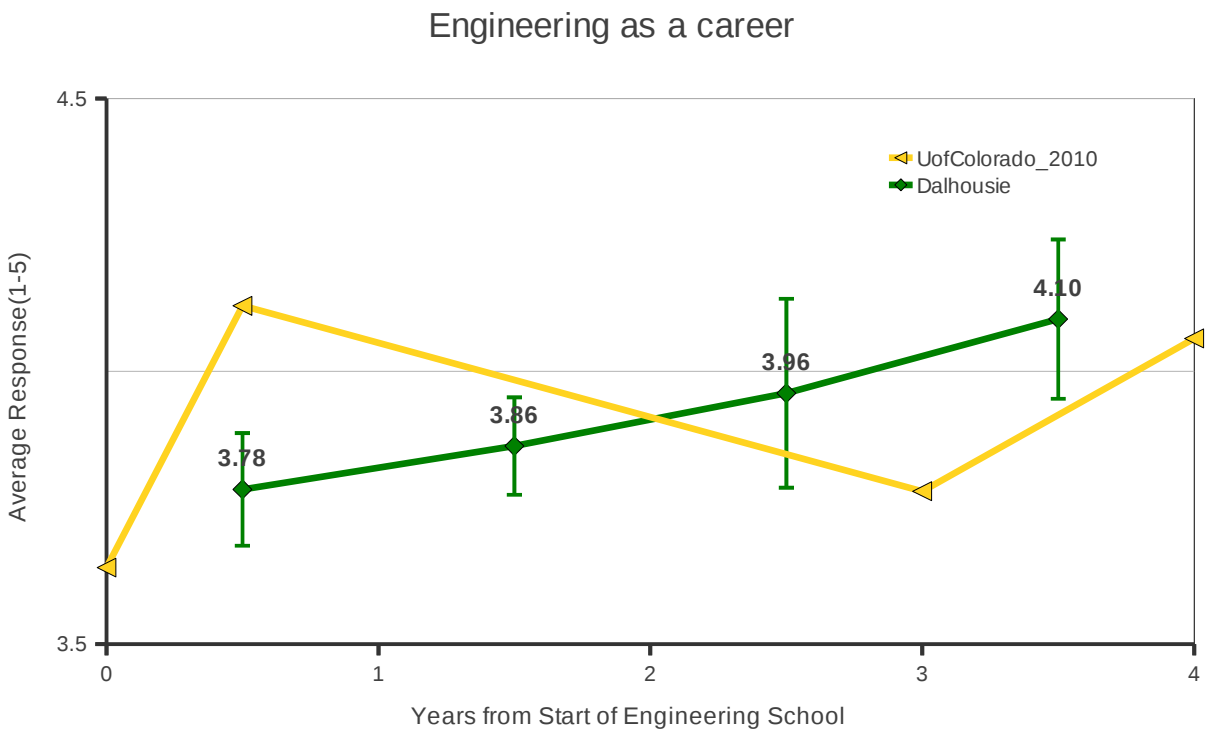

Figure 4: The figure shows the average responses to the combined statements related to "engineering careers" plotted versus the time in University. For comparison, the data from U of Colorado 2010 [6] shows responses to the same statements .

Figure 4, “Engineering as a Career”, indicates that the *Dalhousie University* student confidence in knowledge of the career progresses steadily through the program. The error bars on the plot indicate the 95% confidence interval calculated for the number of responses to all questions collected for the population of students to whom the invitations were sent. The confidence intervals indicate that the increase in the average response from 1st year to 4th year is statistically significant, although the shape of the curve is not necessarily so. In comparison to the published data from *University of Colorado at Boulder*, there appears to be no major jump from one cohort to another, even though the average level of the student's confidence in their knowledge of engineering careers is effectively the same at start and finish of the programs.

Figure 5 “Engineering Methods” shows that *Dalhousie University* students rate their confidence in the engineering methods very low compared to *University of Colorado at Boulder* students. Even though, as Canadians, we cultivate a myth of humility compared to our neighbours, the best explanation for this was proposed by several students after taking the survey. Three commented in person that they felt the “skills' that were specifically mentioned

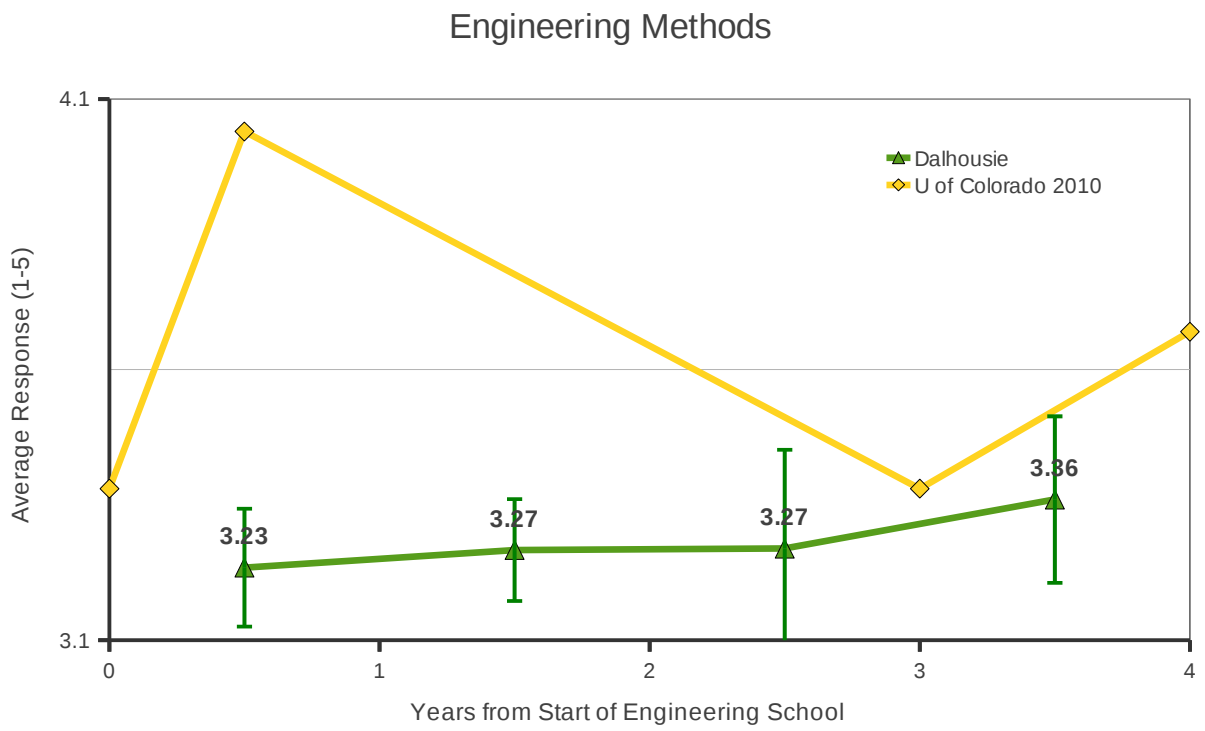

Figure 5: The plot shows average responses to the statements of knowledge in engineering tools and methods. The error bars on the average data show the 95% confidence interval of the survey results.

were narrow. On review, it was clear that some of the questions that mention specific skills targeted those relevant to mechanical engineers. Since the *Dalhousie University* population is only 20% mechanical, it is reasonable to expect that a higher proportion of the respondents were not confident with the specific skills or tools mentioned when compared with the University of Colorado at Boulder population of mechanical engineering students.

Figure 6 shows the average response to statements that were related to skills in Design. The confidence interval for the aggregate results compared to the year-to-year changes in attitudes shows that the students in 2nd year and 3rd year were much less confident in their abilities and knowledge of design. The shape of the curve for their design skills is very different from those means displayed in engineering methods (Figure 5) or engineering careers (Figure 4). The design based statements showed that students lost confidence in the middle years. This, we hope, is due to a lack of courses that give design practice in the middle years, as would be expected in the "bookend" program. In comparison, the *University of Colorado at Boulder* data also showed a loss of confidence when students were surveyed at the start of their final year capstone course.

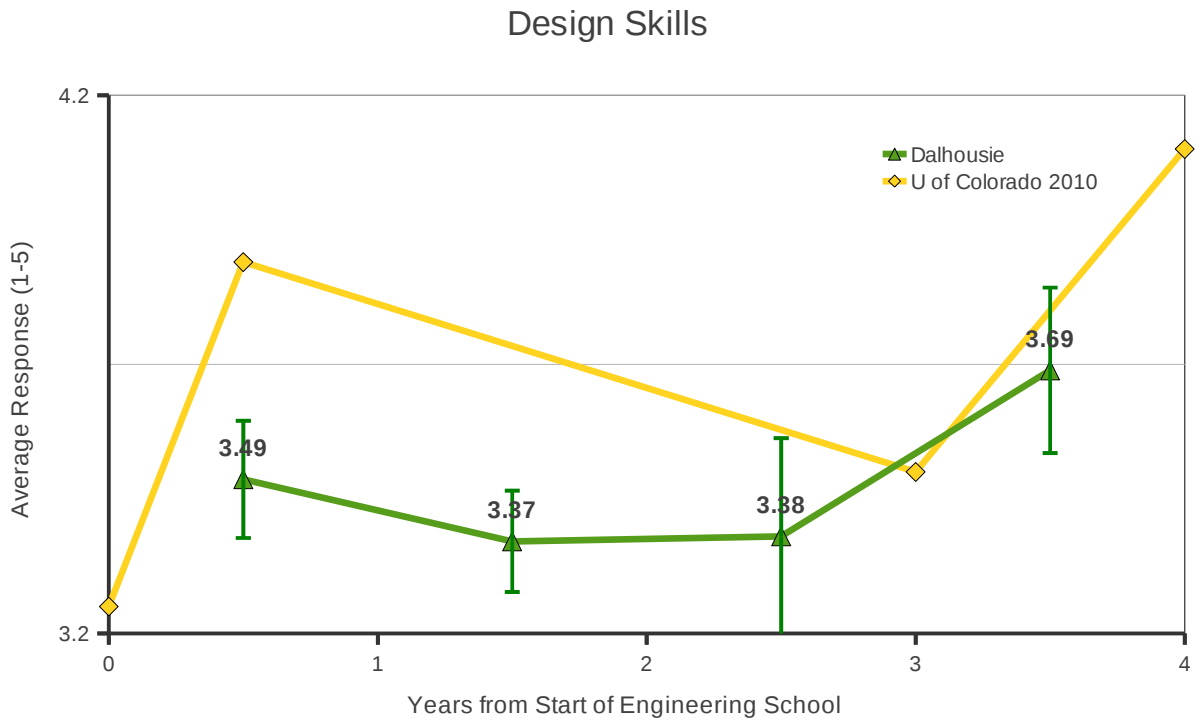

Figure 6: The plot shows the average student rankings for the statements related to engineering design. the error bars show the 95% confidence interval for the survey results. Note the lower scores by students during the middle years of the engineering degree program.

Figure 7, showing students confidence in their communications skills is even more striking. 2nd year students at *Dalhousie University* clearly had a loss of confidence in their skills. Despite the evidence that their rating of these skills improved in 3rd and 4th years, the end result of the student self-confidence in communication at the end of 4 years was the same as in first year, within the statistical confidence interval of the survey. The University of Colorado at Boulder students, however, saw a dramatic increase in their self-assessment of their communication skills by the time they completed their 4th year of studies.

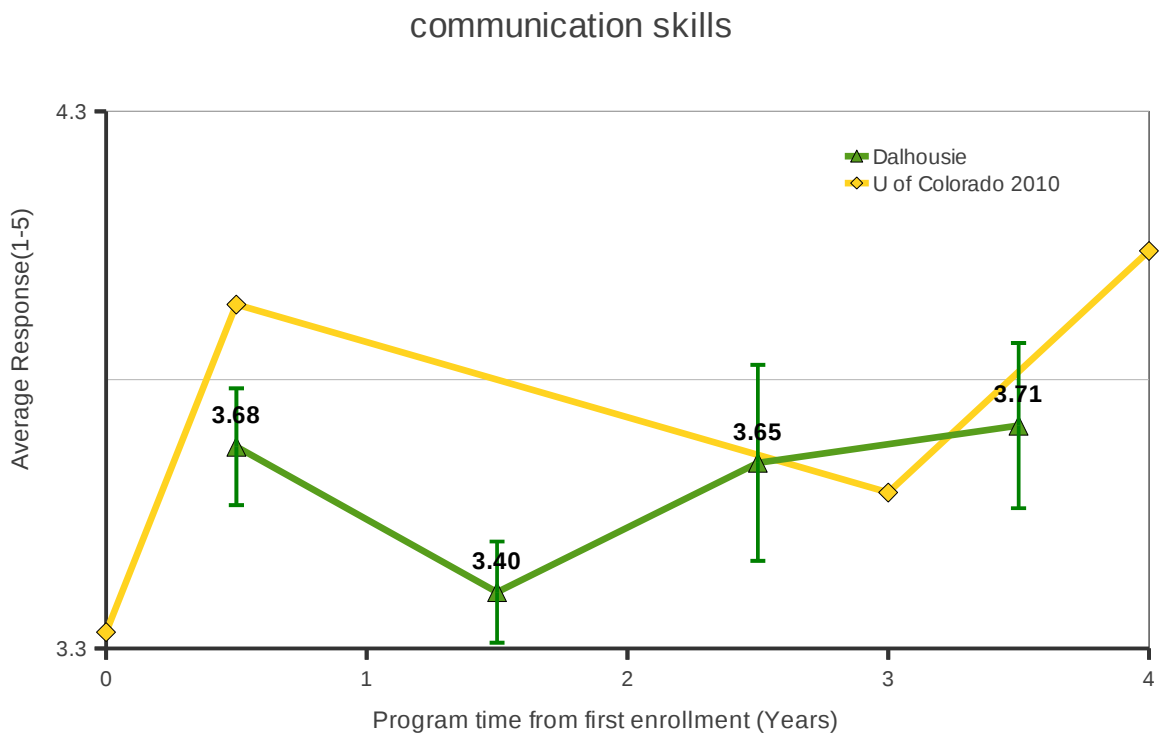

Figure 7: The plot shows student response to statements of their communication skills. The 2nd year cohort had a significant drop in perceived ability, and the overall ranking from beginning to end of university seemed to stay the same for Dalhousie University students.

Figure 8 shows the average attitudes towards the set of statements related to teamwork. Both *University of Colorado at Boulder* and *Dalhousie University* have similar class cohort sizes. The comparison of the student teamwork attitude shows that the *Dalhousie University* students showed a minor drop in the confidence in second year. This may be attributable to the lack of team-based course work in the 2nd year program. Regardless, the increasing trend through the final 3 years of the program is comparable to that seen in the *University of Colorado at Boulder*

survey when we consider that the 4th year class was surveyed at a time when their capstone group design projects were only half complete, while the *University of Colorado at Boulder* students were surveyed after successful completion of a group project.

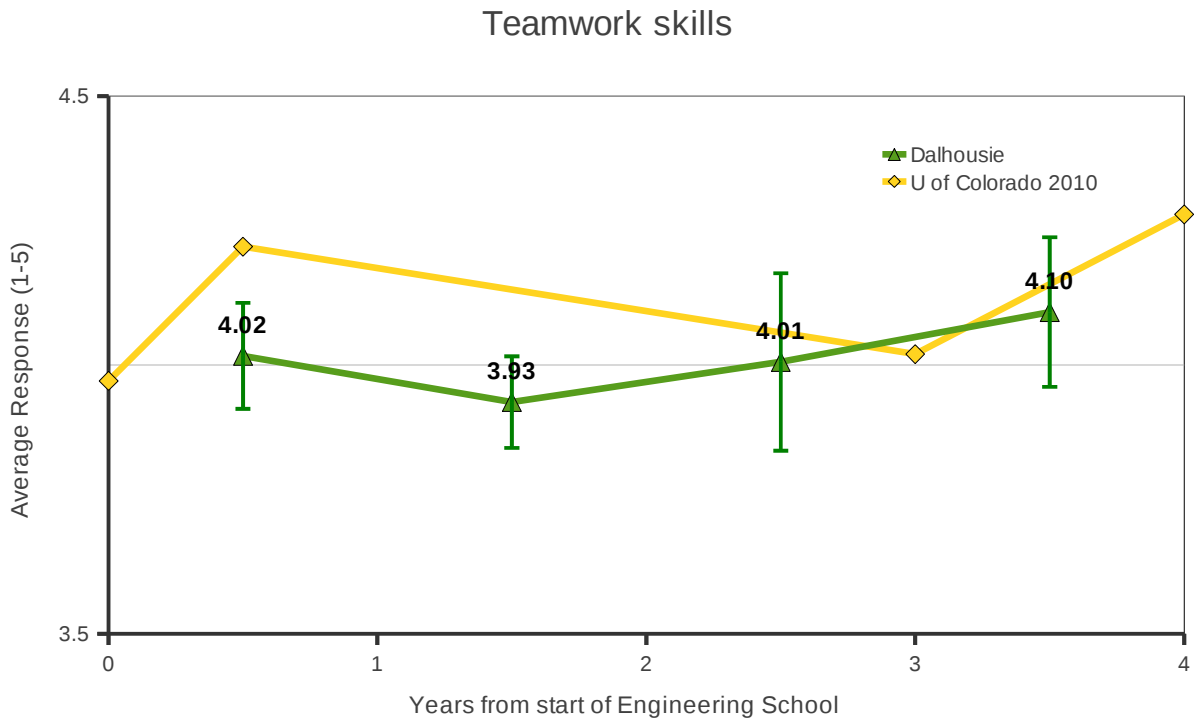

Figure 8: The plot shows a comparison of teamwork rankings. Similar to the ranking in Figure 6, the middle years indicate a loss of confidence. the error bars indicate a 95% confidence interval for the survey data.

Discussion

The survey of *Dalhousie University* students on their self-confidence towards the 5 classification categories revealed that there is a strong similarity between the current survey and prior work by one of the authors. The differences in results are thought-provoking.

The *University of Colorado at Boulder* survey results came from a longitudinal study of mechanical engineering students sampled before and after they encountered significant design courses. It is suggested by the authors[9] that the significant decrease in student confidence in years 2 and 3 is attributable to the lacking PBL design experience (also in years 2 and 3 of the program). The *Dalhousie University* data does not show corresponding significant jumps in attitudes from year to year. This may have been attributable to the lack of significant PBL courses early in the academic program, for the first-year design and graphics course at *Dalhousie*

University is only a partial PBL experience when compared to the full project course offered to students in the first-year of the *University of Colorado at Boulder* mechanical engineering program. Would we have seen an initial jump in *Dalhousie University* student confidence had they been surveyed at the beginning and end of their first-year design course? If not, can the difference between the results at the two Universities be linked to the different levels of project design in the first year course? Will increased use of PBL methods at *Dalhousie University* show significant increase in student self-confidence in the subject areas?

In all of the surveyed areas of self-confidence, the most striking difference was seen between the students average assessment of their abilities in "engineering as a career" compared with their confidence in the *design*, *communication*, and *teamwork* categories. In each of the latter categories, the student assessment from their 1st year to their 4th was within the 95% confidence interval of the survey. These are the areas where PBL can be most effective. Only in students' *knowledge of engineering as a career* is there a significant increase in their self-confidence over 4 years. This issue needs to be addressed in our teaching methods as we begin to encounter the Millenial student.

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