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Engineering Students' Perception of Project Based Learning Activities at the School of Engineering, UBC Okanagan Campus

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Academic Background

• Aug. 2002 Ph.D. In Materials Science and Engineering Department of Mechanical Engineering University of Saskatchewan Saskatoon, Saskatchewan, Canada Thesis Title: Evaluation of Electroless Nickel-Phosphorus (EN) Coatings

• Feb. 1990 Bachelor of Science in Metallurgical Engineering Isfahan (Ariyamehr) University of Technology Tehran square, Isfahan, Iran Thesis Title: Computerized Optimization of the Charge of Blast Furnace

Research Background

• Evaluation of microstructure, physical, mechanical and electrochemical properties of Electroless Nickel-Phosphorus (EN) coatings. This research involved the implementation of various analytical techniques including Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Differential Scanning Calorimetry (DSC), X-ray diffraction compound analysis, Energy Dispersive Spectrometry (EDS), X-ray diffraction pattern, Electrochemical Impedance Spectroscopy (EIS), Fractography etc. in order to conduct a comprehensive investigation on various properties of EN coatings.

• Materials Selection in Potash Brine Environment The application and performance of various materials including stainless steels, ceramics, coatings, titanium and high nickel and chromium alloys subjected to severe corrosion and wear in potash brine environment were investigated. Various experiments including reciprocating corrosion and wear, slurry, and weight loss were conducted as a part of this study.

• Properties of Carbon Nano-tubes Microstructure study of single and multi-wall carbon nano-tubes using TEM investigation. • Fatigue properties of large diameter pipes subjected to girth welding Fatigue properties of girth weld pipes were studied by means of Crack Tip Opening Displacement, CTOD. The microstructural changes in Heat Affected Zone (HAZ) were studied using various experimental techniques including SEM, TEM, nano-hardness and fractography.

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Students' Perception of Project Based Learning Activities at the School of Engineering, UBC, Okanagan Campus

Abstract

The School of Engineering at UBC, Okanagan Campus offers degrees in three engineering disciplines: civil, mechanical and electrical. The first two years of undergraduate study are common to all students and the following two years are specific to disciplines. Through the course of their education, students take part in several interdisciplinary design projects, including three major design projects offered in first and second years and capstone projects in fourth year. In the capstone course, students work on industry motivated real-life projects. In order to evaluate the effectiveness of these project-based learning activities, and to better understand how students evolve through the completion of these projects, a survey was conducted among first year, sophomore and senior students. The survey asked students for their views on the structure of these design courses, the level of difficulty compared to other courses, and how these courses helped them develop the design skills needed in their capstone projects. This paper presents the results from the first two years of the study.

Introduction

What is engineering design? This seemingly simple but in fact rather complex question has been asked by many students. Dym and Little define engineering design as a "systematic, intelligent generation and evaluation of specifications for artifacts whose form and function achieve stated objectives and satisfy specified constraints" [1]. Here, artifacts are human-made objects, such as structures, machines and devices, which have a form (geometry) and function. Further, engineers articulate, design and innovate through their creativity built on the foundation of a thorough understanding of the design process and an integration of technical knowledge and social awareness. The importance of teaching design in engineering education has been highly recognised by Professional Engineering Associations; for example, the Accreditation Board for Engineering and Technology (ABET) and the Canadian Engineering Accreditation Board (CEAB) have recognized facility with design as one of the most important learning outcomes of an engineering education. However, design is difficult to teach because (1) design is a complex cognitive process [2], which requires what are classified in the Bloom's taxonomy [3] as higher-level thinking skills: analysis, evaluation and synthesis. (2) In a traditional engineering curriculum, the integration of coursework from multiple subjects is often inadequate [4]. As a result, students may know subjects well, but may or may not develop the ability to apply their subject-specific knowledge into a design context.

In recent years, project-based learning has been used in many universities such as Purdue's Engineering Projects in Community Service (EPICS) [5], Georgia Tech's Learning by Design™ [6], Stanford's P^{5}BL Lab [7], PjBL across the UK[8] and so on. Research suggests that project-based learning encourages collaborative work [2], enhances students' motivation [2, 9] and improves retention and graduation rates [2, 10].

Since the formation of the School of Engineering at UBC, Okanagan Campus in 2005, engineering design has been emphasized in all three programs: mechanical, civil, and electrical engineering. Design concepts are taught through interdisciplinary project-based learning activities embedded in various courses in all four years. In particular, the importance of introducing engineering design early in the curriculum has been accepted as one of the features of our programs. Thus, three major design projects are introduced to all first year and sophomore students in three courses, namely, a first year course, Engineering Fundamentals (APSC 170), and two second year courses, Applications of Engineering Design (APSC 258) and Mechanics of Materials I (APSC 260). In their final year of studies, students are also required to complete a major capstone design project.

The first year design course focuses on design concepts and process, project scheduling, team building, and the utilization of essential engineering tools for design and analysis. The second year design courses build on this knowledge while integrating newly acquired engineering science materials which students learn in their second year curriculum. All fourth year capstone projects are industry-driven, real-life problems. These problems are more complex and thus require a wider range of technical and interpersonal skills. These capstone projects focus not only on the design process, but also on the creation of feasible solutions.

In order to better understand how effective these project-based learning activities are in enhancing students' knowledge of and experience in engineering design, the instructors of these courses have conducted a survey for first year, sophomore, and senior students in two consecutive years. The survey reveals students' views on the structure of design courses, their level of difficulty in relation to other courses, and the development of design skills toward the fourth year capstone projects.

Brief information on the related courses will be given, followed by the survey methods, results and discussion.

Design project in APSC 170

Engineering Fundamentals (APSC 170) is a first-year design course. The objective of the course is to help first year students develop meta-skills, or the ability to analyze situations and design solutions, to complete projects in a timely manner, to identify professional and social responsibilities, and to communicate technical information. In real design scenarios, engineers develop and exercise these skills through and in a variety of projects, suggesting a "learning by doing" approach. This course consists of three group projects (i.e., failure analysis, sheet metal, and final design project) and diverse tutorial assignments. A variety of topics including engineering drawing, software packages such as SolidWorks, Excel and Maple, and an introduction to shop practices and use of power and hand tools are covered to help students complete these projects. In the final design project, students are given a list of design criteria and a budget. Students work in groups of five or six to generate ideas, which must conform to the design criteria and budget. Upon completion of the final project, students submit reports that include engineering drawings, assembly instructions, calculations, project management charts and tables. A full-day, on-campus design competition is organised for students to present their designs in front of their fellow students and judging panels, which consist of faculty members, engineers from industry, senior and/or graduate students. One example of the final design project is a can crusher consisting of the following sub-sections: (1) a loading mechanism, (2) a sorting mechanism, (3) a counting mechanism, (4) a crushing mechanism, and (5) an energy conversion mechanism.

Design project in APSC 258

The hovercraft project is an integrated design project implemented in Applications of Engineering Design (APSC 258), a sophomore-level design course. The goal of this project is to construct a hovercraft that satisfies requirements in three major areas: structural, fluid mechanics and electrical control system. The design process requires the application of knowledge from other second year courses such as Fluid Mechanics, Analog and Digital Systems, and Mechanics of Materials. For instance, the structure of the hovercraft hull is typically designed as a part of the design project in Mechanics of Materials (APSC 260).

Students are required to design and construct a hovercraft able to maneuver and carry an assigned weight while competing on an obstacle course. As in the first-year design course, designs are evaluated by a group of judges consisting of professional engineers, faculty members, graduate students and undergraduate student members from previously winning teams. Each design team (a group of 5-6 students) is also required to submit three project reports, in which the design process, from the conceptual design stage to the final design, must be properly documented. The competition and the quality of technical reports both contribute to the project mark. Figure 1 shows a group of students working on the hovercraft project.

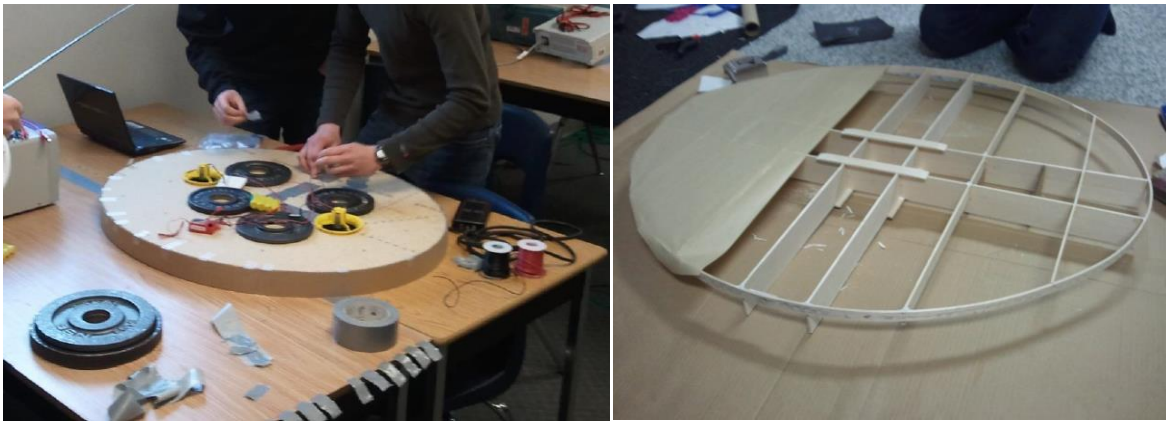
Figure 1: APSC 258 students working on the hovercraft project

Design projects in APSC 260

Mechanics of Materials I (APSC 260) is a sophomore-level course offered to all engineering students in the School of Engineering, UBC, Okanagan campus. The course covers fundamental principles in mechanics of materials including stress and strain, axial loading, torsion, and bending. Over the past five years, two design projects have been introduced. One project was to use balsa wood to design a hovercraft structure that can carry a payload of at least 30 N. This project was conducted in parallel to the overall hovercraft design in Applications of Engineering Design (APSC 258) and with a focus on the design and optimization of beams and trusses. Students worked in teams to develop designs for the hovercraft structure. Each student in a team performed manual calculations for different loading cases to verify and optimize the sizes and quantities of balsa strips (functioned as beams and trusses). Figure 2 illustrates a sample load analysis in a student's report.

The other project dealt with truss bridge design. The objectives of this project were to provide students with further opportunities to practice the engineering design process within the context of mechanics of materials, and to demonstrate the effectiveness of using simulation tools in design. Students were required to design a steel truss bridge to carry a two-lane highway across a river. The software West Point Bridge Designer™ [11] was given to students for generating and evaluating their design ideas. In addition, students were required to perform detailed calculations and analyses. Discussion and reflection on their learning in a team environment throughout this project were emphasized. At the end of the project, students were required to give oral presentations and submit complete design reports. Figure 3 shows a student presentation.

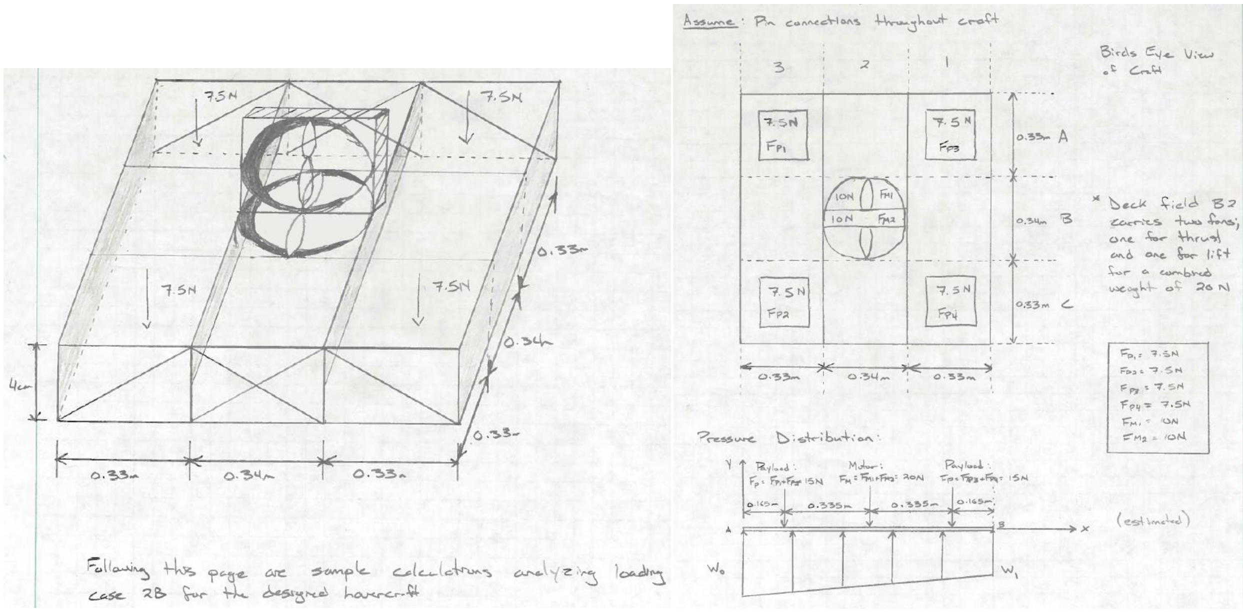

Figure 2: APSC 260 project: hovercraft structure (sample calculations from a student's report)

Figure 3: APSC 260 project: Truss bridge (student presentation)

Capstone projects in ENGR 499

The capstone projects mimic realistic engineering design scenarios, which students will face in the near future upon their graduation. Throughout this course, students form multidisciplinary groups and work on industrial projects proposed by local, national and international engineering companies. Faculty members are actively involved in the capstone projects. In fact, apart from course instructors, each student team is supervised by one faculty member. In addition to technical requirements, this course emphasizes topics such as professionalism, technical communication, engineering law, and ethics. Prominent guest speakers are invited from various industries to offer students valuable insights. Throughout the course, students are required to make three presentations: preliminary, midpoint and final presentations.

Survey methods

In order to evaluate the effectiveness of these design projects in student learning, in the spring of 2012 and 2013, two anonymous online surveys were conducted for first, second and fourth year students. The survey consisted of (1) general questions pertinent to design projects in all of the aforementioned courses, (2) course-specific questions, and (3) questions related to future improvements of the existing course material for all designs. Students answered the questions on the Likert scale of 1-5 (1: strongly disagree, 2: disagree, 3: neutral, 4: agree, 5: strongly agree). The students' responses to part (1) and (3) questions are analyzed and discussed in the following section.

Survey results and discussion

Table 1 lists eight questions in the survey part (1). A total of 348 respondents were received in two years, among which 182 were from freshmen, 109 were from sophomores, 56 were from seniors and 1 student didn't identify his or her year of study. Table 2 shows the number of respondents sorted by discipline and gender. It is noted that the School of Engineering at UBC, Okanagan campus offers two common year curriculum to all students. Although the students are not required to declare their discipline until the end of year two, some first and second year students have indicated their preference in the survey and this was included in the results. The nine students who didn't identify their disciplines were all first year students.

Table 1: Survey part (1) - questions pertinent to all projects discussed in this paper

Question 1	The project was of an appropriate level of difficulty
Question 2	The project encouraged me to review relevant concepts and link theory to practice
Question 3	Peer discussions were important for the success of a design project
Question 4	The project encouraged me to take responsibility for my learning experience
Question 5	The design process helped me develop the ability to generate solutions to a defined problem and make informed choices as to the preferred solution
Question 6	The project provided me an opportunity to further develop my interpersonal and communication skills essential in a team environment
Question 7	The project provided me an opportunity to further develop my organizational and time-management skills
Question 8	The project was assessed fairly (answer this question only if you have received the mark for a project)

Table 2: Number of respondents by discipline and gender

	Mechanical Engineering	Civil Engineering	Electrical Engineering	Discipline not identified
Number of respondents	148	143	48	9
Male	128	121	40	9
Female	17	22	6	0
Gender not identified	3	0	2	0

Question 1: The project was of an appropriate level of difficulty

Table 3 lists the survey results for question 1. The percentage in this table is calculated with all data received in two years. Figure 4 compares the 2012 and 2013 survey results. The numbers in this figure are the average ratings (out of 5) for different courses. The surveys show consistent results. The majority of students thought the projects in these courses were of an appropriate level of difficulty. There were approximately 6~11% of students who disagreed and strongly disagreed. It is interesting to note that the first year students give the highest combined strongly-agree/agree rate 74% and the highest strongly-disagree/disagree rate 11%, which, we believe, may be attributed to the large population of the first year students, their diverse experience/knowledge and general understanding of engineering and science, and their expectations in engineering design practice.

Table 3: Student responses on survey question 1

	APSC 170	APSC 258	APSC 260	ENGR 499
Strongly agree	21%	17%	15%	19%
Agree	53%	50%	39%	34%
Neutral	15%	26%	37%	41%
Disagree	10%	4%	5%	4%
Strongly disagree	1%	3%	4%	2%

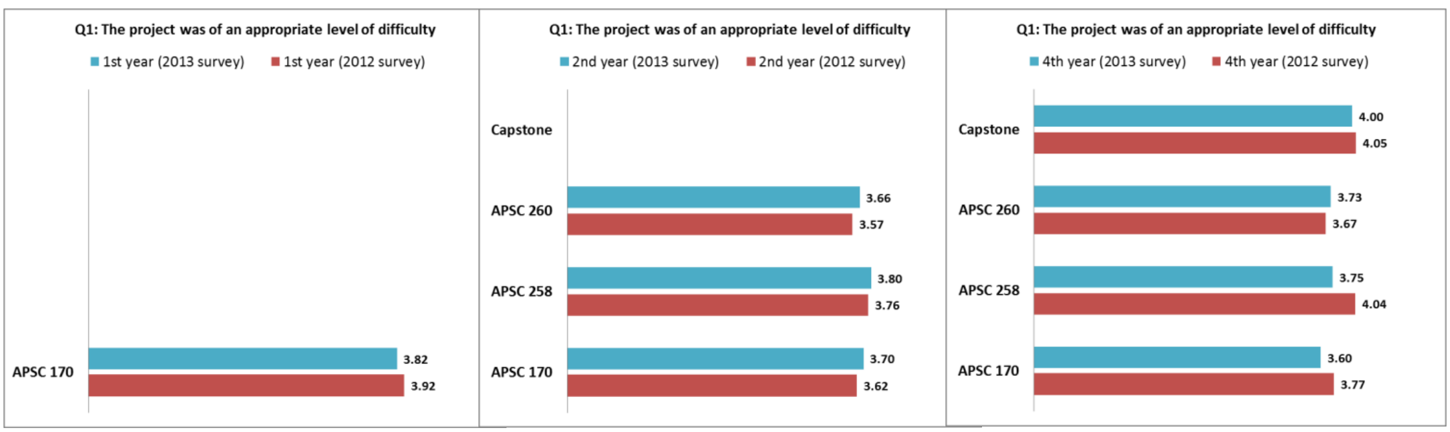

Figure 4: Comparison of 2012 and 2013 survey results for question 1

Question 2: The project encouraged me to review relevant concepts and link theory to practice

Table 4 and Figure 5 give the survey results for question 2. Over 60% of students strongly agreed or agreed that design projects encouraged them to link theory to practice. It is interesting to further analyze senior students' views on these projects as they are close to graduation and they have completed all design project requirement. The senior students give capstone projects the highest rating and the first year project the lowest rating. We interpret this as a result of two reasons: (1) capstone projects range in a wide spectrum of complexity and demand a higher level of knowledge and thinking skills. Students, faculty supervisors and many industry sponsors were highly involved in the whole design process from determining the scope of the projects to finalizing the deliverable results. The nature of these projects and the active involvement of faculty and industry supervisors play an important role in encouraging students to set and achieve greater goals. We have also noticed that students, who are passionate about, or have work experience relevant to their projects, are often self-motivated. (2) On the other hand, the first and second year projects are designed to introduce the design process and create among students an interest and desire in learning engineering disciplines. They are constructed to be entertaining, engaging and educational. As students move to their senior year, and reflect on the projects from their first and second year, the first and second year projects seem to be much easier than what was their initial perception. This may lead to an underestimation of the importance of the lower year projects by senior students. As noted in Olds and Miller [10], students tend to reflect more on the "social aspects" (such as friendship, interaction with faculty and peers) than on the "academic aspects" (such as engineering topics) that they have gained from a design project.

Table 4: Student responses on survey question 2

	APSC 170	**APSC 258**	**APSC 260**	**ENGR 499**
Strongly agree	14%	13%	14%	26%
Agree	50%	48%	45%	24%
Neutral	21%	27%	33%	43%
Disagree	12%	10%	4%	4%
Strongly disagree	3%	2%	4%	3%

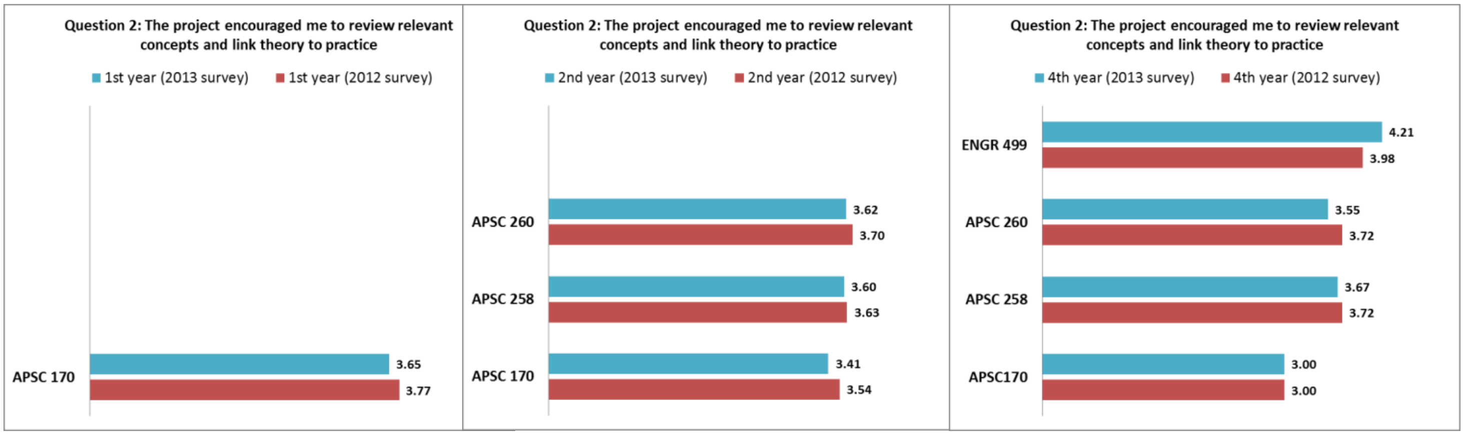

Figure 5: Comparison of 2012 and 2013 survey results for question

Question 3: Peer discussions were important for the success of a design project

Peer discussion plays an important role in the design process, particularly in projects that require substantial collaborations. Table 5 and Figure 6 show that the majority of students in APSC 170 and APSC 258 rated in favor of this question (strongly agreed or agreed). The projects in both courses require students to design and make prototypes (such as the can crasher and hovercraft) to demonstrate and compete in public. Substantial teamwork and collaboration are essential to the success of this type of project. In contrast, the projects in APSC 260 are of a different nature. They focus on calculations and simulations. Teamwork is required to generate and discuss design ideas; at the same time, individual calculations and simulations are equally valued. It is interesting to observe that although capstone projects still received a high rating for this question, more senior students gave a neutral answer. We are not sure if senior students prefer to work more independently or lack time for teamwork due to time constraints as virtually all senior students have discipline-specific projects to complete in other courses.

Table 5: Student responses on survey question 3

	APSC 170	**APSC 258**	**APSC 260**	**ENGR 499**
Strongly agree	58%	41%	30%	34%
Agree	30%	36%	30%	17%
Neutral	9%	21%	31%	45%
Disagree	2%	1%	6%	3%
Strongly disagree	1%	1%	3%	1%

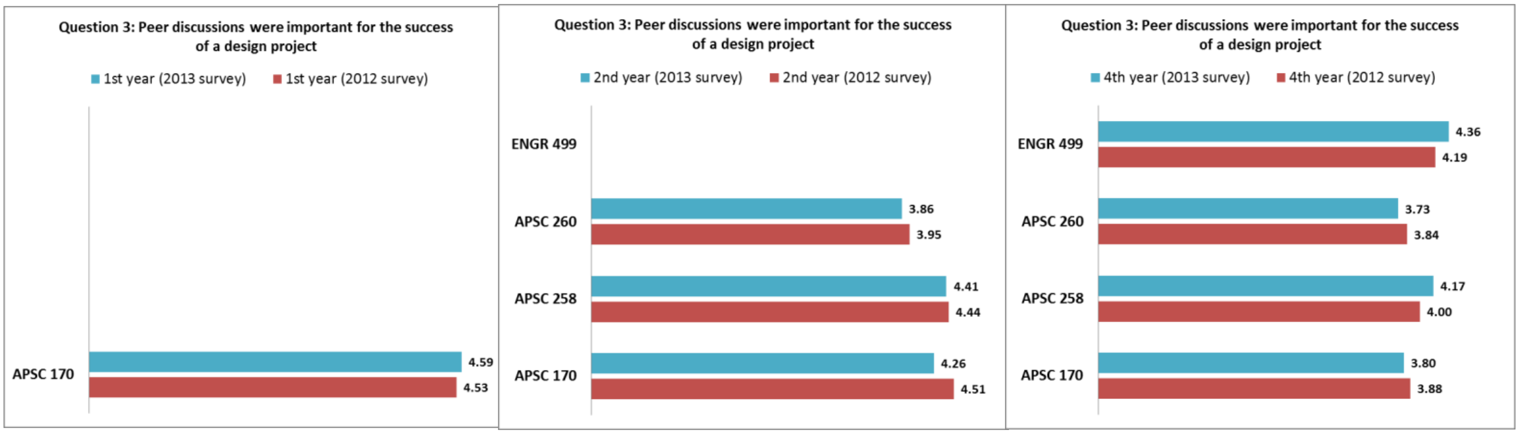

Figure 6: Comparison of 2012 and 2013 survey results for question 3

Question 4: The project encouraged me to take responsibility for my learning experience

As seen in Table 6, the majority of students agreed, to different degrees, that these projects encouraged them to take responsibility for their learning. Students' views on the first and second year design projects in this aspect are similar with APSC 170 receiving a higher rating. In the capstone course, 36% of students strongly agreed with this question. This is partially due to the complex nature of capstone projects, which often challenge students to explore, filter and absorb a large amount of information. In many cases, this learning process is guided by faculty supervisors, but in some cases, students have to take the full responsibility if the area is out of the faculty supervisor's expertise. As students enter the senior year, they become more responsible and independent learners and appreciate more the importance of self-learning.

Table 6: Student responses on survey question 4

	APSC 170	**APSC 258**	**APSC 260**	**ENGR 499**
Strongly agree	31%	16%	14%	36%
Agree	52%	54%	50%	22%
Neutral	12%	26%	28%	38%
Disagree	4%	3%	7%	2%
Strongly disagree	1%	1%	1%	2%

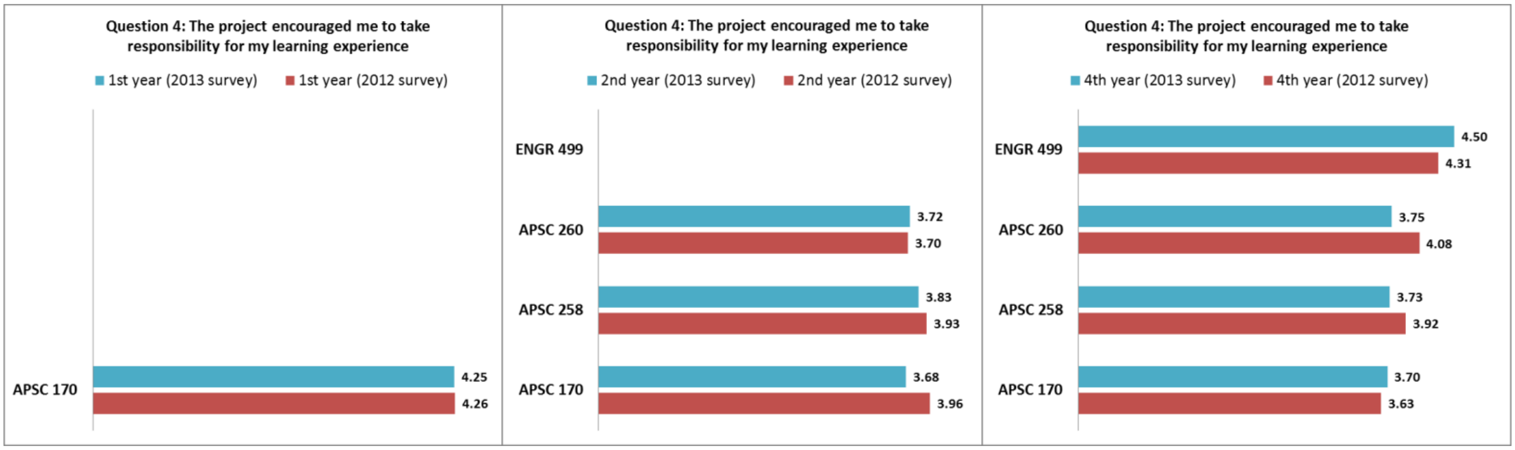

Figure 7: Comparison of 2012 and 2013 survey results for question 4

Question 5: The design process helped me develop the ability to generate solutions to a defined problem and make informed choices as to the preferred solution

Table 7 and Figure 8 show student responses to this question. In APSC 170 and APSC 258, 82% and 78% of students strongly agreed or agreed to this question, respectively. In both APSC 260 and ENGR 499, 54% of students strongly agreed or agreed to this question. A common feature of APSC 170 and APSC 258 is that both are integrated design courses with major projects, which require model building and testing. The positive response in these courses indicates the importance of experiential experience in student learning. For freshmen and sophomores in particular, fun activities and hands-on experience not only help students understand the design process, but also enhance their interest in engineering. Projects involving a vast amount of literature reviews or calculations, as those in APSC 260 and ENGR 499, may be less appreciated by students. As students move to their fourth year, they tend to give higher weight to the capstone projects than to the first and second year projects.

Table 7: Student responses on survey question 5

	APSC 170	**APSC 258**	**APSC 260**	**ENGR 499**
Strongly agree	26%	25%	7%	25%
Agree	56%	53%	47%	29%
Neutral	14%	19%	34%	39%
Disagree	3%	2%	9%	5%
Strongly disagree	1%	1%	3%	2%

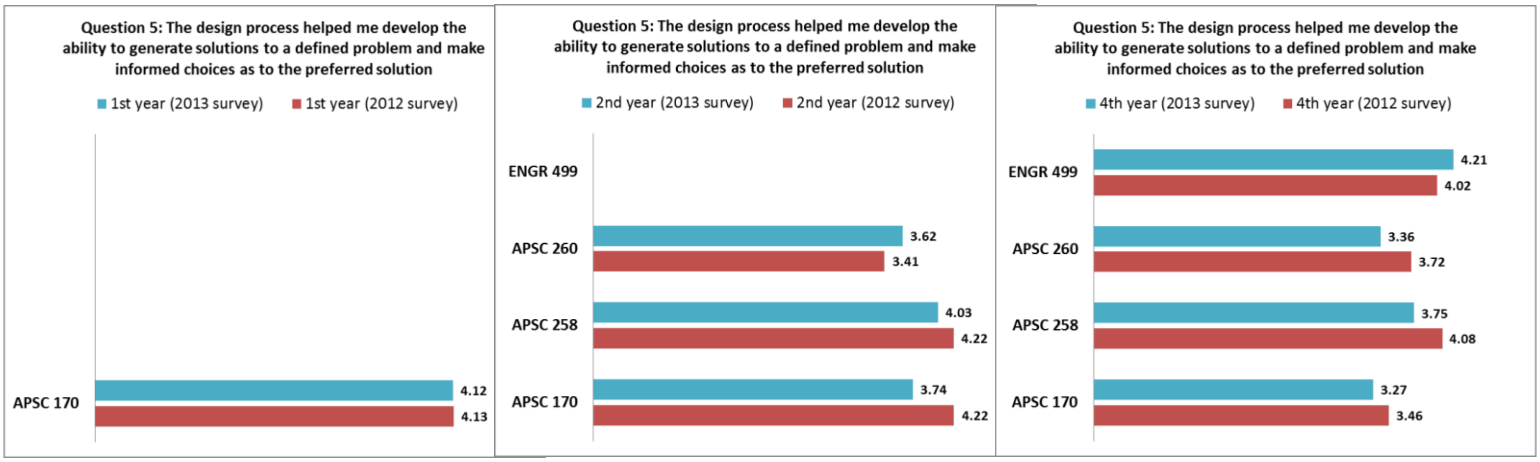

Figure 8: Comparison of 2012 and 2013 survey results for question 5

Question 6: The project provided me an opportunity to further develop my interpersonal and communication skills essential in a team environment

All of these design projects involve group exercises, discussion and presentations. For example, the capstone course requires students to make four oral presentations (including a poster presentation and a final presentation) and to submit three reports and a professional logbook. APSC 170 and APSC 258 projects include interactive tutorials, laboratory work and design competitions. All of these factors contribute to the development of students' interpersonal and communication skills. The majority of students generally agreed to this, as can be seen in Table 8 and Figure 9. From students' comments, we realize that some groups faced challenges such as a mismatch of students' strengths, inactive participation of certain members, and difficulties in reaching agreements among team members. Such problems may exist in all kinds of collaborations to a certain degree. These projects provide students with a miniature environment in which to practice how to deal with those issues.

Table 8: Student responses on survey question 6

	APSC 170	**APSC 258**	**APSC 260**	**ENGR 499**
Strongly agree	35%	34%	18%	30%
Agree	48%	44%	39%	27%
Neutral	13%	20%	34%	41%
Disagree	3%	1%	7%	1%
Strongly disagree	1%	1%	2%	1%

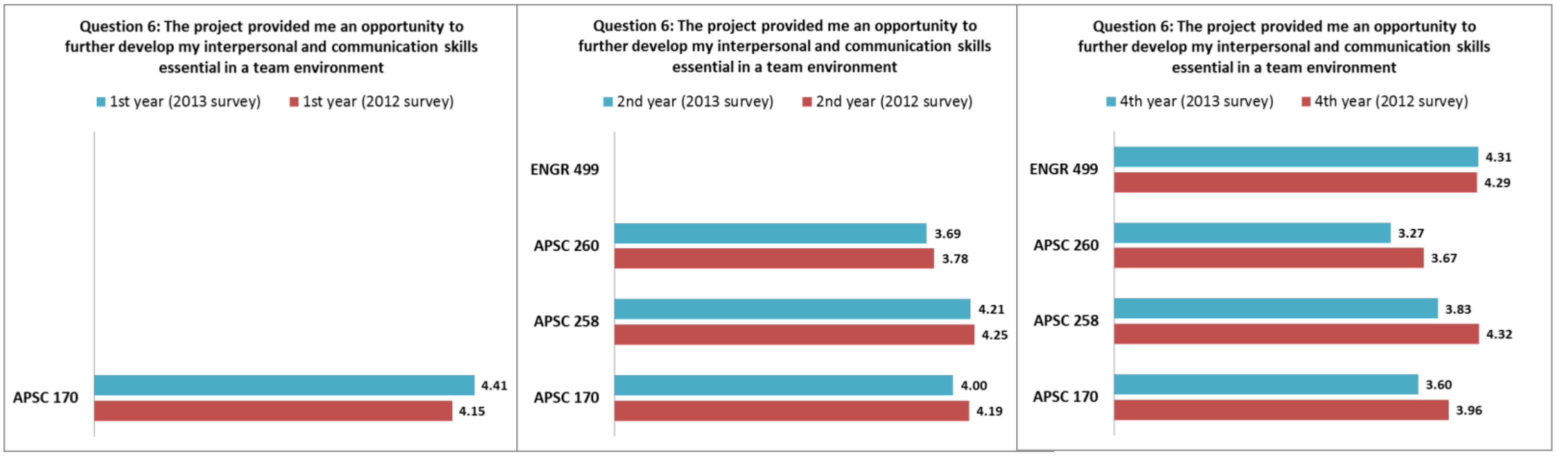

Figure 9: Comparison of 2012 and 2013 survey results for question 6

Question 7: The project provided me an opportunity to further develop my organizational and time-management skills

Organizational skills are important to the success of a design project. Figure 10 shows consistent results for this question in the 2012 and 2013 surveys. Table 9 indicates that these projects had a positive influence on students in terms of their organizational and time management skills. Students' views on this aspect were relatively consistent over the years surveyed, with senior students giving a higher rating on capstone projects than on other projects.

Table 9: Student responses on survey question 7

	APSC 170	**APSC 258**	**APSC 260**	**ENGR 499**
Strongly agree	30%	28%	18%	33%
Agree	53%	51%	43%	25%
Neutral	13%	17%	32%	39%
Disagree	3%	3%	5%	1%
Strongly disagree	1%	1%	2%	2%

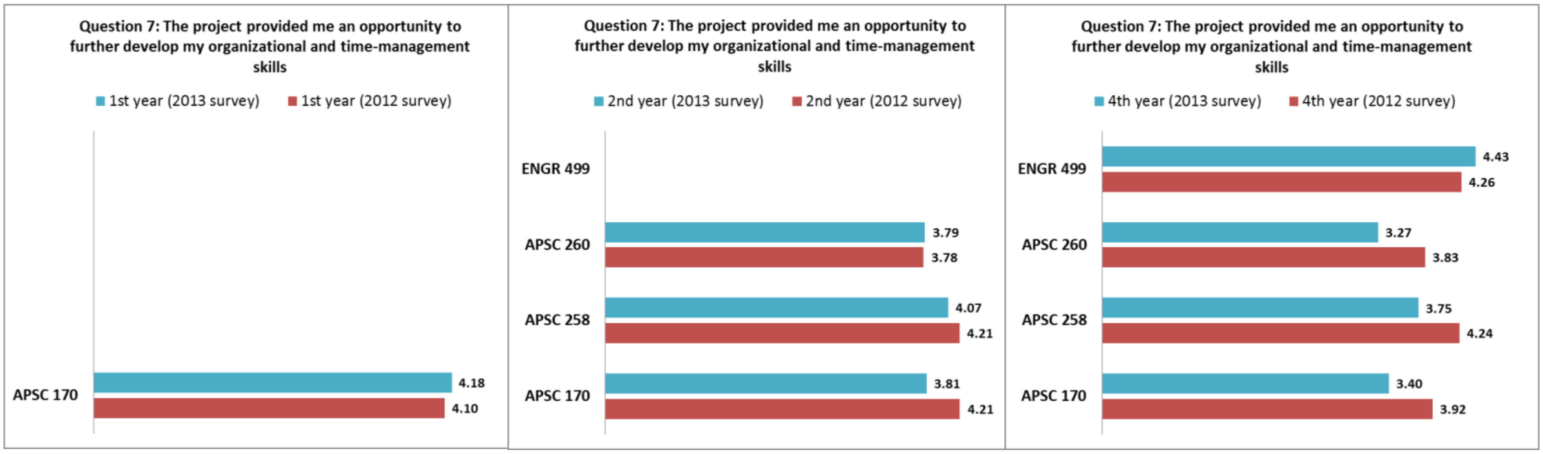

Figure 10: Comparison of 2012 and 2013 survey results for question 7

Question 8: The project was assessed fairly (answer this question only if you have received the mark for a project)

Table 10 and Figure 11 show student responses to this question. Three first and second year projects received similar and fairly consistent results in the 2012 and 2013 surveys. The capstone course, however, received the lowest rating. The challenge in assessing group projects lies in the fact that the assessment strategy often involves multiple facets such as proposal, progress, presentations, reports and other deliverables. For examples, the assessment scheme in the capstone course consists of eight components covering oral presentations and reports in different stages of the course. In addition, the assessment involves multiple parties, which adds additional complexity. Even with a well-thought marking scheme, it may still be challenging to assess an individual's contribution in a team work. The first and second year projects are well structured and given to all students in the same class. This made the assessment process slightly less challenging because the same marking scheme can be implemented in all teams by the assessors in a more consistent way. In comparison, capstone projects are different from each other in many ways. For example, some projects involve feasibility studies of new ideas; some are the continuation of existing projects; some projects are interdisciplinary; and some may require knowledge primarily in a specific discipline. In spite of the complexity of assessing design projects, effective assessment strategies must be developed and implemented to improve design education. In Davis et. al. [12], three design educational outcomes are defined as design process, teamwork and design communication. The need remains for a further development of an integrated assessment strategy which addresses these three categories. Moreover, the assessment strategy should be robust and easily communicated to different parties who may be involved in the assessment process.

Table 10: Student responses on survey question 8

	APSC 170	APSC 258	APSC 260	ENGR 499
Strongly agree	19%	14%	9%	4%
Agree	54%	46%	51%	31%
Neutral	21%	30%	31%	45%
Disagree	3%	8%	8%	7%
Strongly disagree	3%	2%	1%	13%

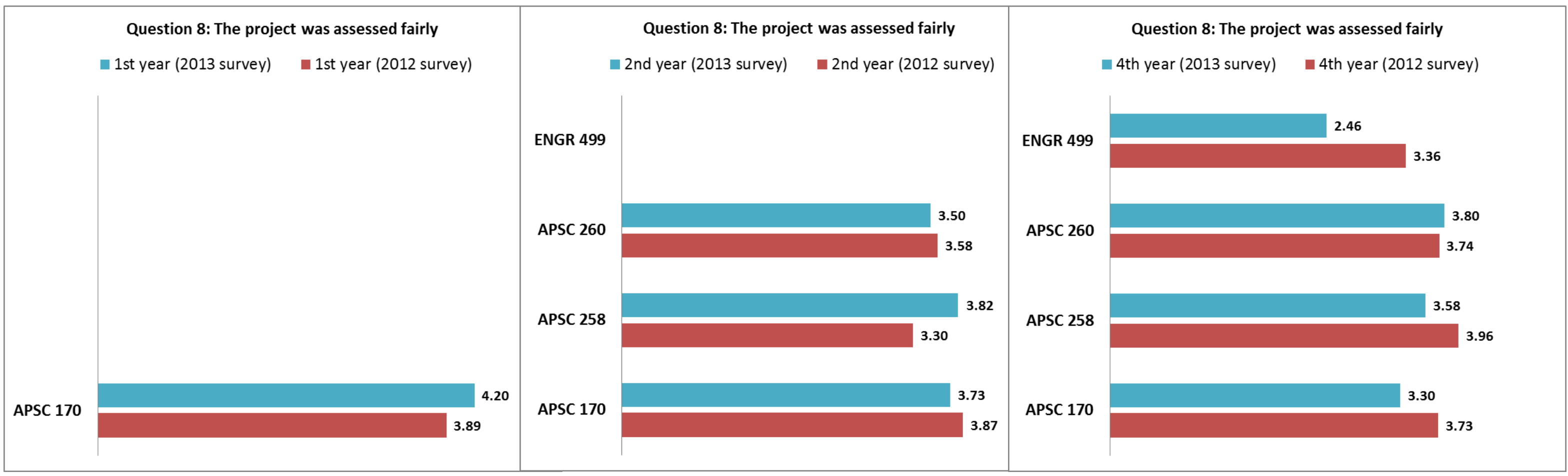

Figure 11: Comparison of 2012 and 2013 survey results for question 8

Questions in survey part 3

In addition, this survey includes questions related to future improvements of the existing course material for all designs. These questions are listed in Table 11. The survey results are shown in Figure 12. The numbers in this figure are the average ratings (out of 5) from students in different years of study. A high number indicates a high desire for instructions on a specific topic. Among the five questions in this category, questions 10 and 12 received the smallest numbers. This is because the technical communication skills and the ability to use database have been emphasized in the first and second year curriculum. In addition to individual communication courses, students practice these skills through design projects. Questions 11 and 13 received the highest numbers, indicating the importance of machine shops and simulation software in student design education. Hands-on experience is valued by students in all four years. A better use of machine shops and tools will greatly enhance student learning experience through design. Simulation software has become an essential tool in design. Senior students have shown a particular interest in learning more software, which may partially due to the complex nature of capstone projects. A thorough instruction on simulation software will help students not only improve the efficiency in their designs but also better develop analytical and critical thinking skills. A successful implementation of design courses requires resources and support from the department and institution.

Figure 12, question 9 also reveals students' opinion on the first and second year design courses, which are taught individually within a specific course structure. More interaction with non-design courses may help students better integrate knowledge from different courses. However, this seemingly obvious practice is challenging for individual instructors to implement, as interaction among different courses takes instructional time and may reduce the amount of course content that can be covered. Will less content, more interaction provide students with a better long-term learning outcome? Additional study is needed in this area.

Table 11: Survey part (3): questions related to future improvements of the existing course material for all designs

Question 9	I would like to see more interaction between design courses and other courses offered in first and second years
Question 10	I would like to see more instruction on the use of technical libraries and database to assist me in my projects
Question 11	I would like to have more access to machine shop, hand- and power- tools, machine shop time and more hands-on experience
Question 12	I would like to receive more help from technical communication instructors
Question 13	I would like to receive more instruction on various simulation software

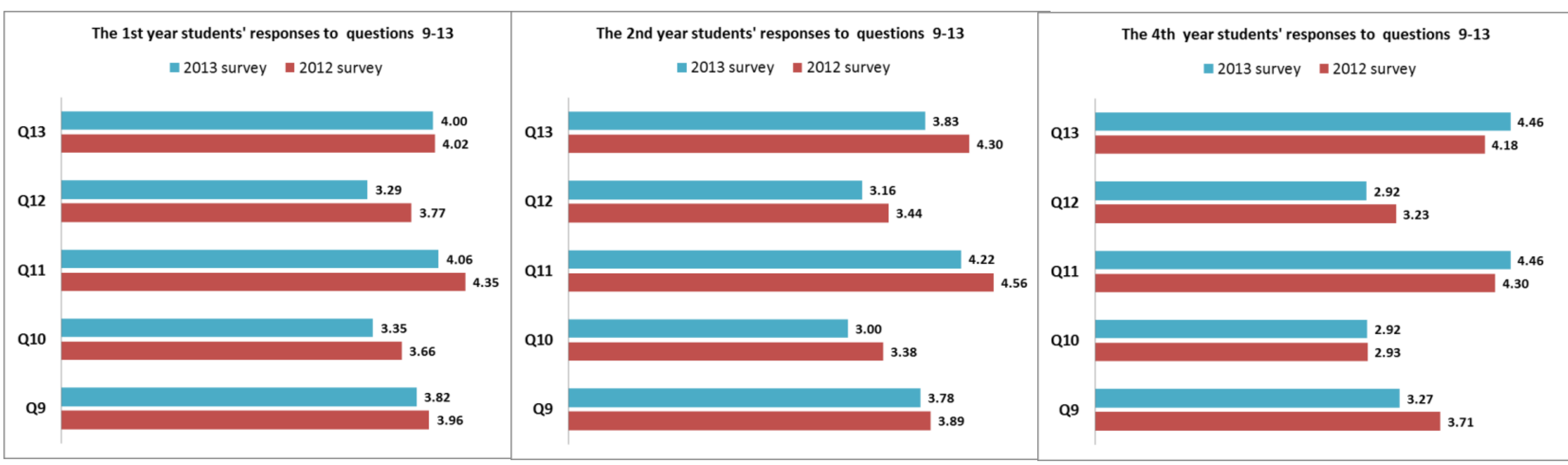

Figure 12: Comparison of 2012 and 2013 survey results for questions 9-13

Conclusion

The Accreditation Board for Engineering and Technology (ABET) and the Canadian Engineering Accreditation Board (CEAB) have identified design education as an important criterion in engineering curriculum. Project based learning has been widely used in engineering programs to develop students' team-based design capabilities. It is important for engineering faculty to understand the learning outcomes from design projects. In this survey, students' views on three first- and second-year design projects and capstone projects are evaluated. By summing the percentage in the agreed and strongly-agreed columns, we have identified the top aspects that students valued in projects:

- Engineering Fundamentals (APSC 170): (1) peer discussion, (2) take responsibility for my learning, (3) organizational/time- management/communication/interpersonal skills
- Applications of Engineering Design (APSC 258): (1) organizational and time-management skills (2) communication/interpersonal skills, (3) the ability to generate solutions and make informed choices
- Mechanics of materials I (APSC 260): (1) take responsibility for my learning, (2) organizational and time-management skills, (3) peer discussion
- Capstone projects (ENGR 499): (1) take responsibility for my learning, (2) organizational and time-management skills, (3) communication/interpersonal skills

As can be seen, many students appreciate the organizational and interpersonal skills gained through design projects. As project based learning shifts the focus from an instructor-centered teaching model to a student-centered learning model, students' motivation becomes critical to the success of this type of learning activities. The projects in our curriculum have a positive impact on student learning in terms of motivation, knowledge integration and self-learning skills. We believe the positive impact is attributed to the following strategies such as involving students in decision making, role play in class, increasing student-faculty interaction and providing students with hands-on experience.

Project criteria and constraints, the availability of materials and tools and students' prerequisite knowledge and skills play significant roles on the level of creativity, learning and success in design projects. As a result, the faculty who teach design must determine an appropriate theme and scope of a design project, carefully examine the level of challenge and establish achievable objectives and deliverables.

Engineering design is collaborative work. Depending on the theme of projects, different levels of collaboration are required among students. Peer discussion is generally valued by students. It is of particular importance to first year students as it not only helps them complete projects successfully, but also provides them with opportunities to form study groups and develop social connections, which are important to their success in later years of study. Strategies that help create a supportive learning environment will reduce frustration related to teamwork in projects and will enhance students' learning experience.

Through our study, we have also identified the importance of assessment. As noted in Davis et. al. [12], "systematic assessment is challenging yet necessary for program improvement." As virtually all design projects consist of multi-dimensional factors such as proposals, meetings, project journals, presentations and reports, assessment is particularly important. As a result, instructors should make every effort to develop clear, consistent and effective assessment strategies, and more importantly, communicate these strategies unambiguously to students and any parties who will be involved in the assessment process.

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