



Assessing Graduate Attributes Within a Two-Semester Capstone Design Course

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Abstract

Having a two-semester Capstone Design course for students in their senior year of an undergraduate engineering degree program affords the opportunity to assess many attributes as students ready themselves for graduation because of the comprehensive nature of the project-based course. This paper explores how graduate attributes (GrAtts), as defined by the Canadian Engineering Accreditation Board (CEAB), are assessed within a Mechanical Engineering Capstone Design course. Assessment of GrAtts is necessary for CEAB accreditation, not only for demonstrating that students have been exposed to and assessed on these attributes, but it also provides valuable information necessary for continuous improvement activities within programs. The Mechanical Engineering Capstone Design course deliverables and evaluation methods have been developed to incorporate many of the GrAtts within the activities necessary for completing the course. Specifically, this course assesses the GrAtts of: problem analysis, investigation, design, individual and teamwork, communication skills, professionalism, economics and project management, and lifelong learning. Standard assessments were developed for a diverse set of projects supervised by multiple faculty members who assess the deliverables. Grading rubric templates were developed to help standardize the grading of the projects by various faculty members. Overall, defining a common set of course deliverables and grading rubrics across the projects was found to be beneficial. The assessments provided useful data on the achievement of the GrAtts. This course has used these deliverables and assessments for one academic year. Based on faculty and student feedback, adjustments to the rubrics are being made in preparation for subsequent offerings of the course. Finally, this paper will discuss how GrAtts assessment data will be used in the continuous improvement activities for curriculum development within the Mechanical Engineering undergraduate degree program.

Introduction

Since the fall of 2014, it has become necessary for undergraduate engineering programs in Canada to demonstrate that their graduates possess twelve Graduate Attributes (GrAtts) as part of the accreditation process by the Canadian Engineering Accreditation Board (CEAB).¹ Obtaining accreditation is of great importance to undergraduate engineering programs because the term “engineer” is regulated in Canada. For example, in Ontario, the practice of professional engineering is regulated by Professional Engineers Ontario (PEO). In order to be granted a professional engineer (P.Eng.) license from PEO, an applicant must “hold an undergraduate engineering degree from a Canadian Engineering Accreditation Board (CEAB)-accredited program (or possess equivalent qualifications).”²

Similar to Accreditation Board for Engineering and Technology (ABET) accreditation in the United States,³ CEAB accreditation also ensures that programs are continually improving. Assessment of twelve CEAB GrAtts and use of the outcomes to inform decisions on curriculum and program development enables continuous improvement activities. The complete list of CEAB GrAtts is provided here:¹

1. A knowledge base for engineering
2. Problem analysis
3. Investigation
4. Design
5. Use of engineering tools
6. Individual and teamwork
7. Communication skills
8. Professionalism
9. Impact of engineering on society and the environment
10. Ethics and equity
11. Economics and project management
12. Life-long learning

Although students will develop all GrAtts throughout their undergraduate engineering programs, assessment of the attributes in the final year of the students' programs provides information on the achievement of the attributes at/near graduation. With this in mind, the two-semester Capstone Design course for students in their senior year of their undergraduate engineering degree programs assesses eight of the twelve CEAB GrAtts (problem analysis, investigation, design, individual and teamwork, communication skills, professionalism, economics and project management, and lifelong learning). This paper will examine how the Mechanical Engineering Capstone Design course assesses the achievement of GrAtts and how the assessment data can be used to continually improve the Mechanical Engineering undergraduate degree program and curriculum.

Literature Review

Development of course learning outcomes and valid assessment methods in engineering education has recently become an area of increased focus in Canadian universities since the adoption of GrAtts assessment by the CEAB. With GrAtts assessment roll-out as part of the accreditation procedure being fully implemented this year,¹ institutions have been developing formal procedures and practices in earnest over the past few years in preparation for upcoming accreditation visits. Programs undergoing review in 2015 are the first required to report data regarding GrAtts assessment. As such, the body of research literature in Canada in this field is relatively immature as compared to that of the United States, where ABET accreditation procedures have been focused in this regard since they introduced accreditation reforms via Engineering Criteria 2000 (EC2000) in 1999.³

As in the USA, where Capstone Design Courses have been the focus of assessment of ABET outcomes,⁴ Canadian schools are placing focus there as well. Most of the literature regarding Canadian Engineering concerns the process by which course assessment or learning outcomes can be linked to CEAB GrAtts. In fact, many course syllabi in the Faculty of Engineering at the University of Windsor use much the same language as the CEAB document in describing the course learning outcomes.

Unique to many engineering Capstone Design courses is the necessity of multiple instructors and/or industry advisors to act as assessors for students enrolled in one course. Student

assessment can vary widely as a function of the individual assessor, not to mention the differences in projects. Davis⁵ supports the use of multiple assessors to mitigate the effects of bias associated with individual assessors. The goal is to ensure fair and uniform assessment of outcomes achievement for each student.

Another interesting aspect of assessing GrAtts for engineering students is related specifically to issues that arise as a matter of performing group project work that is so common in engineering design courses. Sorensen and Todd⁶ highlight the difficulty of developing assessment methods that ensure fair and individualized assessment in the Senior Capstone Course environment at Brigham Young University, where so much of the work is performed by student groups.

The Capstone Design course at the University of Windsor also faces the same challenges listed above; variations in assessor feedback, and providing individualized assessments for group projects. This paper will focus on how the course is assessing the CEAB GrAtts; however, insight into how the aforementioned challenges have been handled will also be discussed.

Course Format

The Mechanical Engineering Capstone Design course is a two-semester course that places students in teams to complete an open-ended design project in the final two semesters of their degree program. The teams work as a “company,” to produce specific deliverables: a design proposal that includes a cost analysis and schedule, a progress report and poster, construction and commission of the design apparatus, and a final report and presentation. It is expected that the design has both global and detail completeness.⁷

The class meets for two hours, once each week. During these meetings, there are workshops and presentations on various topics such as technical writing, presentation skills, design philosophy, and discipline-specific topics such as computational fluid dynamics and materials in engineering design. Each design team must register for a four-hour laboratory section. The laboratory session provides time for teams to meet as a group and with their advisors from industry and academia. Technicians are also available to supervise fabrication work within the laboratory. This course has a total credit weight of eight hours (i.e. four hours per semester).

In general, team sizes should vary from four to about fifteen team-members, depending on the project. In 2014, team projects included the design of research-focused laboratory equipment, competition-based projects, and industry-sponsored design projects. The full list is provided in Table 1 along with the number of students in each group. The projects are quite diverse; however, the undergraduate program must ensure that all students develop the GrAtts necessary for engineering. Thus, all teams must meet common milestones and deliverables for their individual projects. Assessment of items ensures that the students are meeting the course learning outcomes.

Table 1: 2014 Capstone Design projects by category showing number of students in each group as a percentage of the course enrolment

<i>Research-focused/Laboratory</i>	<i>Competition-based</i>	<i>Industry-sponsored</i>
Wave Flume (4%)	SAE Formula (17%)	Novel Crankshaft Design (4%)
Vibro-Wind Generator (also presented at competition) (9%)	SAE Aero Design (6%)	High Pressure Wash Bay Camera Monitoring System (8%)
High Pressure Die Casting for Magnesium (3%)	SAE Baja (17%)	Flexible Design of Robot End Effectors (5%)
Torsion Test Rig Fixture (6%)	Electric Vehicle Grand Prix (EVGP) (14%)	Modular and Flexible Tool Design (6%)

GrAtts and Course Learning Outcomes

The course learning outcomes were developed as a group that included input from the Capstone Design course coordinators from multiple undergraduate engineering programs and the faculty's Undergraduate Programs Coordinator. Although each Capstone Design project is different, each student should achieve a common set of learning outcomes.

Once the course learning outcomes were determined, they were mapped to the CEAB GrAtts.¹ From this exercise, it was established that the Capstone Design course had learning outcomes that supported the following GrAtts:

- Problem Analysis
- Investigation
- Design
- Individual and Team Work
- Communication Skills
- Professionalism
- Economics and Project Management
- Lifelong Learning

The course deliverables are described in Table 2 with respect to GrAtt assessment. It is important to note that while it is possible to assess more GrAtts for each deliverable, focus is placed on specific items for this inaugural formal assessment as the procedure is developed.

Table 2: Graduate Attribute assessment for course deliverables. (†Numbering corresponds to GrAtts as listed by Engineers Canada¹; *denotes items graded by multiple faculty/graduate assistants/technical staff).

		Graduate Attributes [†]							
		3.1.2 Problem Analysis	3.1.3 Investigation	3.1.4 Design	3.1.6 Individual and Team Work	3.1.7 Communication Skills	3.1.8 Professionalism	3.1.11 Economics and Project Management	3.1.12 Lifelong Learning
<i>Deliverables (% of final grade)</i>									
Group Grade	Letter of Intent* (5%)	X			X	X		X	X
	Progress Poster Presentation* (10%)			X	X	X			
	Written Progress Report (10%)			X					X
	Written Final Report (40%)	X	X	X		X	X	X	X
	Final Project Presentation* (15%)				X	X			
Student Grade	Individual Professional Conduct and Productivity (10%)					X	X		
	Class/lecture Participation (5%)								X
	Peer Evaluation* (5%)						X		X

For the first five items in Table 2, all members within each group received a common grade while each student received an individualized grade for the last three items in the list. As well, those items marked with an asterisk were graded by multiple assessors made up of faculty, course graduate assistants, and technical staff members (or fellow students, in the case of peer evaluation).

The schedule of course deliverables is shown in Figure 1. Note that the final course deliverables occur prior to the final examination period for the semester that ran from August 14 – 22 in that particular year.

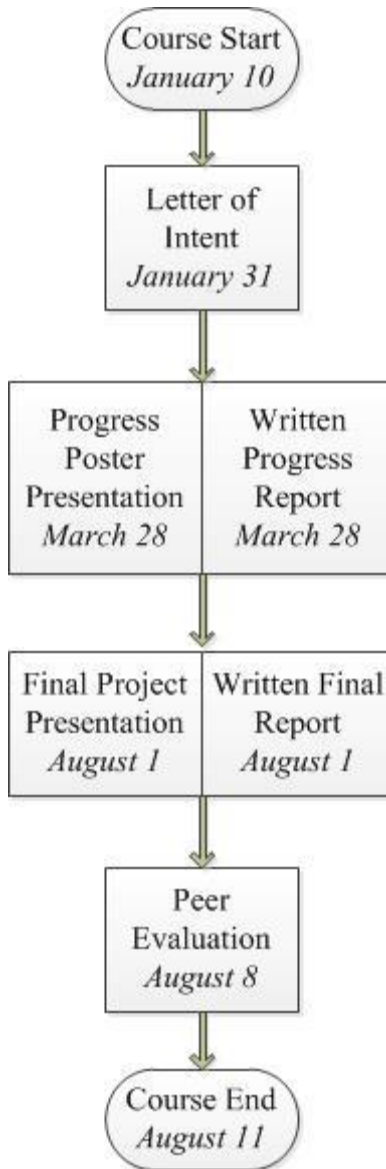


Figure 1: Course deliverables and due dates.

Graduate Attribute Assessment Results and Analysis

Rubrics were created to help assessors focus on the assessment of the course learning outcome elements assigned to each item. The rubrics assisted in uniformity and thoroughness as multiple assessors were utilized for the aforementioned items. The rubric that was used for assessing the final project presentation is shown in Table 3. Similar rubrics were used for the remaining assessments with indicators for each of CEAB’s GrAtts¹ taken from the Global Outcomes⁸ for the Faculty of Applied Science & Engineering at the University of Toronto.

Note that assessors were provided the following definitions to complete the rubric:

- FAILS: Not clear or concise, much applicable information is missing;
- MARGINAL: Somewhat clear and concise, some applicable information is missing;
- MEETS: Somewhat clear and concise, all applicable information is present; and
- EXCEEDS: Clear and concise, all applicable information is present.

Table 3: Grading rubric for the final project presentation; assessors were asked to select the appropriate level for each line item and also provide an overall assessment, providing comments as necessary.

<i>Assess the group's ability to:</i>		FAILS	MARGINAL	MEETS	EXCEEDS	COMMENTS
3.1.6 Individual and Team Work	6a) Establish and monitor team organizational structure					
	6b) Promote team effectiveness through individual action					
	6c) Successfully complete a team-based project					
3.1.7 Communication Skills	7a) Identify and credibly communicate engineering knowledge					
	7b) Demonstrate the ability to use different modes of communication					
	7c) Develop communication through an iterative process					
OVERALL EVALUATION OF PROJECT PRESENTATION		FAILS	MARGINAL	MEETS	EXCEEDS	

Note that no numeric values are present on the rubric. The goal in conducting qualitative assessments was to eliminate the differences between assessors in assigning a number grade that might ultimately bias the averaged score based on individual preference. Values were assigned

to each assessment level (fail: 1, marginal: 2, meet: 3, exceed: 4) and weights assigned to each learning outcome category depending on the particular assessment in order to calculate the overall grade once all the completed rubrics were collected.

Although many GrAtts were assessed throughout this course, only the results of the assessed learning outcomes associated with “Design” are shown in Figure 2, Figure 3, and Figure 4 to demonstrate how the collected data are being used for continuous improvement activities and for CEAB accreditation. It should be noted that Design is the fourth GrAtt, thus, the learning outcomes associated with it have been labeled 4a, 4b, 4c, and 4d, as shown in Figures 2, 3, and 4.

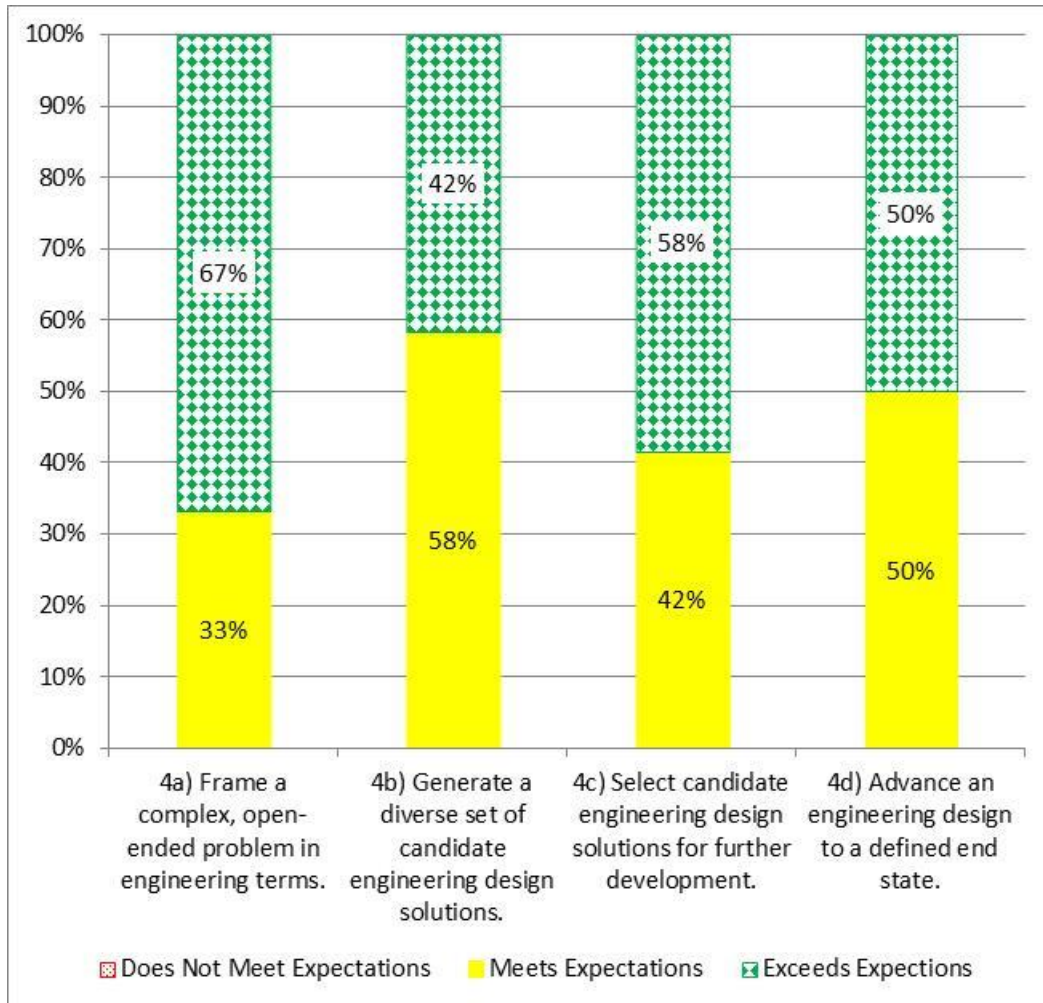


Figure 2: Design course learning outcomes results for the progress poster presentation submitted by all Capstone groups for Winter/Summer 2014. For each learning outcome, the percentage of project groups that did not meet, met, or exceeded expectations are shown. Note that all groups met or exceeded the expectations.

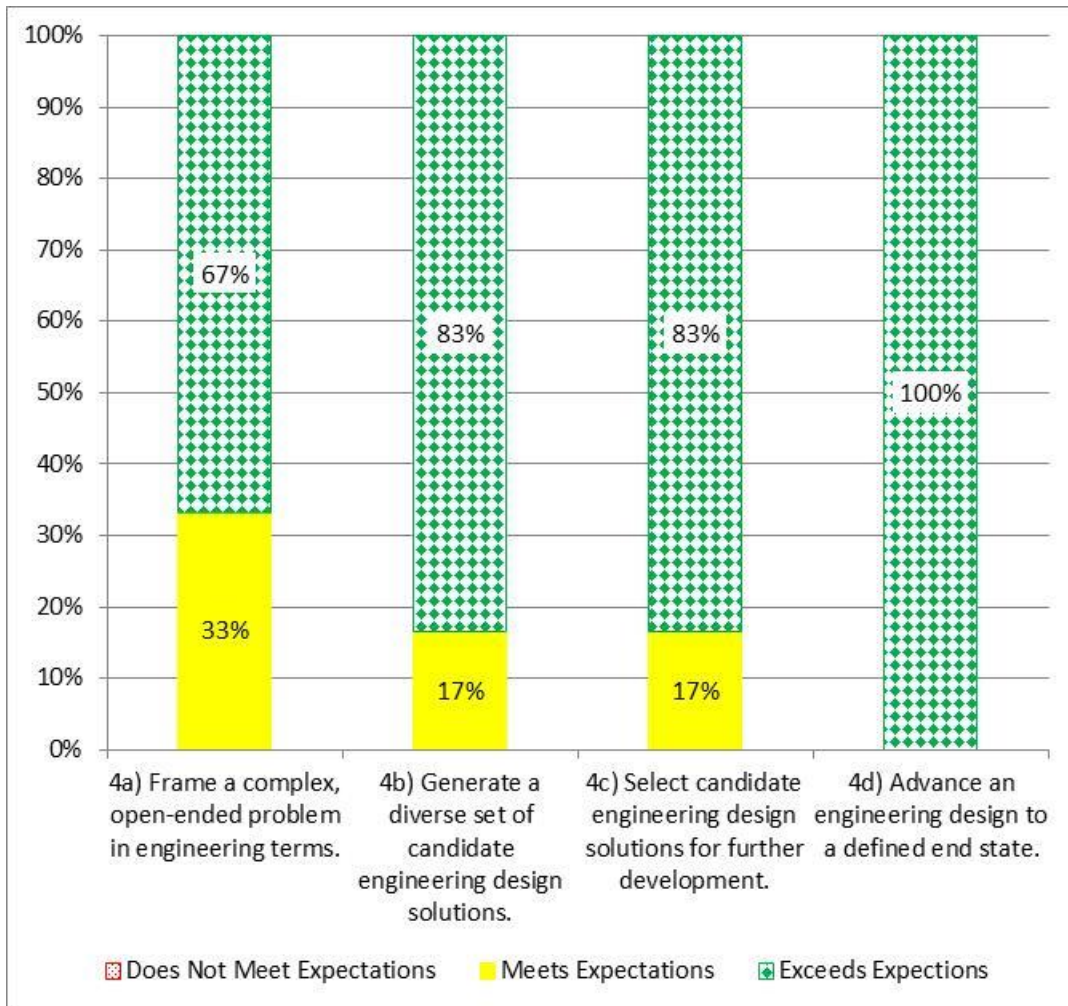


Figure 3: Design course learning outcomes results for the progress reports submitted by six of the twelve Capstone groups for Winter/Summer 2014. For each learning outcome, the percentage of project groups that did not meet, met, or exceeded expectations are shown. Note that all groups met or exceeded the expectations.

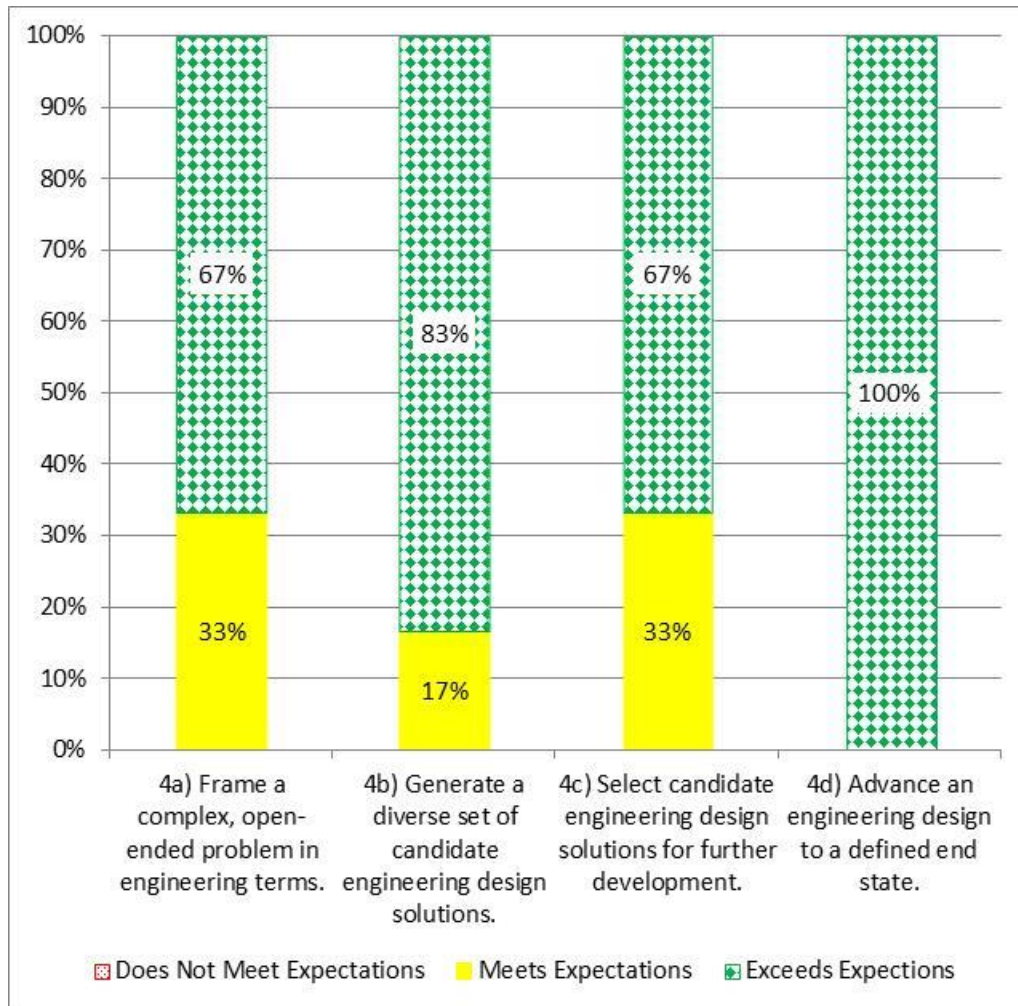


Figure 4: Design course learning outcomes results for the final reports submitted by six of the twelve Capstone groups for Winter/Summer 2014. For each learning outcome, the percentage of project groups that did not meet, met, or exceeded expectations are shown. Note that all groups met or exceeded the expectations.

Since this is a two-semester, senior-level course, students and faculty place a high importance on the successful completion of the Capstone Design projects. For this reason, it is expected that most students and teams will do well, i.e., meet or exceed expectations. This is evident in the assessment results shown in Figure 2, Figure 3, and Figure 4.

The data reported in Figures 2 and 3 were assessed at the same point in the course (after approximately three months). It's interesting to note that with the ability to ask questions of specific students in each group during the poster presentation, the results for students exceeding expectations decreases for design learning outcomes 4 b, c, and d. This targeted interview aspect of the poster presentation assessment helps to improve the ability to accurately assess each group's progress as a whole by examining each member with regard to their contribution to the group – an aspect not possible within the scope of a written report, where it's possible that some group members' contributions might be minimal compared to others. It is somewhat challenging

to compare the results of Figures 2 and 3, measured at the same time, as data for only half of the projects are included in Figure 3 compared to all groups reported on in Figure 2.

It is interesting to note the percentage of groups meeting and exceeding expectations for design learning outcome 4a is unchanged in each of the three figures. This result likely connects to the fact that the framework of the Capstone projects was communicated and maintained by the Capstone advisor early in the course (generally, this framework would need to be in place for the Letter of Intent submission during the first month of the course). With the historical presence of many of the projects, framework variation from year to year would be carefully examined by the individual advisors.

Note that while it was possible to report on the Design learning outcomes assessment for all Capstone groups for the progress posters, where multiple assessors were required to submit their rubrics to the course coordinator for summarizing, the same was not true for the progress and final reports. In the case of the reports, where single faculty were asked to provide assessment and report grades for their groups, the response rate for providing the rubrics was only 50%. As such, Design learning outcomes assessment is only reported for six of the twelve groups for the progress and final reports.

Continuous Improvements

As part of the continuous improvement process, various stakeholders were consulted: faculty advisors, course coordinators for various undergraduate programs, course graduate assistants, and students in the course. A list of potential course and assessment modifications was generated to address the achievement of the course learning outcomes and GrAtts by students in this course. The list is as follows:

- Requirement for assessors to submit completed rubrics as part of the grade submission process on the course website to ensure a comprehensive data set following course completion;
- Review of the rubrics to ensure that all the categories chosen for reporting for each deliverable are relevant to *all* Capstone projects;
- Incorporation of assessor feedback to rubrics to ensure comprehensive ease of use;
- Multiple assessor requirements for as many deliverables as possible to remove individual bias;
- Qualitative rubric grading processes to mitigate individual bias;
- Including student logbooks in the course assessment;
- An annual review of the course lectures (via a survey) to offer relevant topics in a timely manner in subsequent course offerings.

It is widely recognized that outcomes achievement cannot only take place after students have completed their program of study. At Washington State University, Davis⁹ reported that measuring learning outcomes for Engineering Design is not only an important task to be performed at the conclusion of the program, but also reveals critical information when carried out at the mid-program point. Setting appropriate levels of expectation at these two intervals will ensure that attributes development occurs appropriately as the graduate moves into the professional phase of their career. The data that results can be used in curriculum review, a key

activity associated with continuous improvement of engineering education. This is the ultimate goal for the implementation of GrAtt assessment at many points within a curriculum as part of the CEAB accreditation process. Thus, the Mechanical Engineering Capstone Design data points provide a final measurement, but not the only measurement, of students' achievement of particular GrAtts.

Conclusions and Recommendations

This course provided assessment data for the CEAB GrAtts. Through the use of grading rubrics, the differentiating assessment was provided to students and teams. However, recommendations for modifications for future course offerings have been made.

At the time of writing, this course is being offered, and various modifications have been made based on the results of the offering discussed above.

Future areas of study of interest to the authors include:

- Investigation of the effect of student group vs. individual grading in the context of the deliverables specific to Capstone Design courses;
- By examining the results of learning outcomes achievement on a student-by-student basis rather than a group-by-group basis, the effect of project group size on successful learning outcomes achievement can be examined and optimal group sizes can be determined.

Although many of the GrAtt assessments within the Capstone Design course are performed on group work rather than individual work, the Mechanical Engineering program provides many assessments of individuals throughout the curriculum. The GrAtt assessment data from this particular course provides additional data points in order to gauge the achievement of the CEAB GrAtts in a comprehensive, longer-term (two semesters) group project that is more representative of the projects that students will perform in the workplace after graduation than shorter projects that the students perform in other courses.

Finally, the Mechanical Engineering program at the University of Windsor is using the GrAtt assessment results from this course and other courses to better understand students' development throughout their careers. The program is using this information to implement improvements and track the results.

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