Fostering "Soft-Skill" Graduate Attribute Development using Multifaceted Instructional Strategies in an Undergraduate Engineering Course

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***Abstract*— The Engineering Safety and Risk Management (ESRM) course at the University of Alberta was identified as exemplifying the development of two graduate attributes, professionalism and ethics and equity. Traditionally considered 'soft-skill' attributes, these are not easy to teach and even more difficult to assess. Using multifaceted teaching, this instructional team explicitly integrated 'soft-skills' with those knowledge skills traditionally required in ESRM. Results indicate that students in this course showed improvement in their development and understanding of these graduate attributes when compared to previous iterations of this course.**

***Index Terms*— blended learning, graduate attributes, teaching practice, risk management instruction.**

Introduction

Recently designated a mandatory course for all incoming University of Alberta engineering students, ENGG 404, *Engineering Safety and Risk Management - Leadership in Risk Management*, taught by the David and Joan Lynch School of Engineering Safety and Risk Management (ESRM), course offerings are growing from 150 to over 1,100 students per academic year. This increase in enrollment poses substantial challenges for the instructional team, such as: maintaining course quality, delivering content specific to each field of study, continued inclusion of a collaborative team project, and adapting assessment administration to manage the larger class sizes. To meet these challenges it was required to restructure the course. The new course structure and content would need to be scalable, need to be tailored in part for the various fields of study, and need to maintain or, preferably, improve quality of instruction.

As class sizes increase, the University of Alberta Faculty of Engineering prepares for its program accreditation. To meet these requirements, ENGG 404 was identified as representing two of the 12 Canadian Engineering Accreditation Board (CEAB) Graduate Attributes (GAs)[1]: "Professionalism" and "Ethics and Equity".

Prior to re-structuring the course, ENGG 404 relied on didactic lecture and one-way delivery of information in the classroom. Traditional lectures were utilized in both the 1 hour lecture and 1.5 hour seminar periods to cover all necessary information. In-class face-to-face opportunities to analyze, apply, and evaluate information were limited. This, combined with having to reach a significantly larger student population, led the instructional team to seek instructional methods alternative to the traditional lecture to enhance the learning opportunities for students.

As engagement and improved student learning experience are at the heart of blended learning [1], it was decided that blending ENGG 404 would be an appropriate instructional shift for this course. In general, the term "blended learning" applies to any course with more than one mode of content delivery, with one of these modes typically being online [2]. By moving some of the content delivery from in-class lecturing onto the online learning management system, students could work through material at their own pace, opening class time to provide guided practice of the skills normally practiced individually outside of class [2]. Blended components for teaching and delivery of course content were introduced in the Fall of 2016. These multifaceted, blended components included instructor-written courseware content, delivered both in traditional lectures as well as through online readings and videos, guided in-lecture peer-to-peer discussions and active learning experiences, instructional and working seminars, guest speakers, case studies, assignments, collaborative project work, and online examinations.

As our pedagogical strategies shifted to better serve an increased enrollment, the instructional team considered whether these new representations would improve development of intended GAs, as well as the student learning experience. As engineering faculty find it difficult to implement non-technical attributes, particularly attributes related to ethics, in a specific way [3], we began to analyze our implementation of those 'soft-skill' attributes of interest; in addition to the faculty specified GAs, "Professionalism" and "Ethics and Equity", the instructional team is of the opinion that this course's

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[1] See the *2016 Accreditation Criteria and Procedures: Revised February 2017*, available at https://engineerscanada.ca/accreditation/accreditation-resources for the full list and definitions of the 12 Graduate Attributes as defined by the Canadian Engineering Accreditation Board.

content and structure also addresses "Lifelong Learning" and "Individual and Team Work". We use the term 'soft-skill' to represent those non-technical, complementary skills required by the CEAB (and industry) of all engineering graduates. Hence, we asked, *how might 'soft-skill' attributes manifest in a multifaceted engineering course?* To address this question, this paper will discuss these multifaceted instructional components as they foster the development of the four selected CEAB GAs: Professionalism, Ethics and Equity, Lifelong Learning, and Individual and Team Work. In an effort to narrow the focus of this paper, components implemented purely for logistical reasons are ignored in favour of those with a pedagogical significance.

I. Background

A. Course Context

ENGG 404 has the following course description in the University of Alberta 2017-2018 Calendar Course Listings.

> "Basic concepts of risk and consequences of loss incidents; risk management principles and practices; incident investigation, causation, root cause analysis; process safety management; the roles of government agencies, professional bodies and industry associations; process safety; workplace safety; risk-based decision-making processes; leadership and the human-factors side of risk management. The course focuses on the principles and practices of leadership towards the effective application and implementation of risk management in major organizations across all engineering disciplines. Industry virtual tours, case studies, seminars and team projects specific to the student's engineering program will be used to develop competencies and proficiencies in applying leadership and organizational effectiveness for successful risk management" [4]

Scheduled instructional time in the University of Alberta Calendar for each enrolled student consists of 150 minutes of lecture time and an average of 90 minutes of seminar time per week for 13 weeks [4]. Seminars are scheduled such that a few seminars are 150 minutes in duration, and during others the time is returned to students as voluntary working time. Course content is delivered mainly through custom courseware written by members of the ESRM School and with content from invited guest speakers [5].

Prior to restructuring the course format, lectures were one-way transmission of information, from professor to student [5]. Seminar time was typically didactic and used for longer guest speaker presentations, minimal instruction on the team project, and some student work time. This voluntary work time was intended for students to work on the team project but there was no planned interactive instruction between the professor and students; the students either used their common-scheduled time to work on the project, or they did not.

One major core component of the course is the team project, which requires students to conduct an incident investigation and root cause analysis for an industrial operation that has experienced a loss incident. Hence, the instructional team decided to focus on blending the seminar time to enhance students' interaction with the instructional team and the practice of the course material as they progress through the team project. In the new blended format, content is delivered in lecture, online (through videos, readings, and quizzes), and applied within the seminar. In the seminar, students now practice their skills on a case study undertaken by the entire class. After this scaffolded practice time, the instructor reviews potential solutions, giving students feedback on their attempts. Finally, students are given the bulk of seminar time to complete this portion of their team project with instructor support available. This system builds on content covered online and in lecture while providing learning experiences which promote growth in student understanding of each section of the report and content retention.

Teams are assigned by the instructional team based on: program and plan (where possible, to simplify collaborative meetings outside the seminars), academic achievement (mean GPA was 3.2), comfort level with technical and colloquial writing, and a blend of students' "personal working styles" as determined by an on-line exercise. Assignations were made targeting a team size of 4 members; teams occasionally had 3 members, and all efforts were made to ensure these teams would be composed of members that demonstrated above average academic performance. Prior to blending, personal working styles were determined by an in-class, instructor-led activity, and team members were selected from different programs and plans to encourage a multidisciplinary team approach. The corresponding issues with this approach were: i) the use of time for in-class activity was inefficient, and ii) any potential benefits of diversity in expertise were significantly offset by the difficulty of the teams to schedule collaborative meetings. After blending, the students' personal working styles were determined by a mandatory self-report survey done on-line, and team members were selected from the same program and plan, i.e. their classmates, with beneficial common schedule and an opportunity to select a loss incident common to their field of study.

B. Canadian Engineering Accreditation Board Graduate Attributes

As of 2014, all accredited Engineering programs in Canada are required to provide evidence supporting their implementation of twelve graduate attributes. The Faculty of Engineering at the University of Alberta selected ENGG 404 to assess the development of student competencies in "Professionalism" and "Ethics and Equity" as part of the CEAB accreditation process. As the content and structure of the course also lends itself to the development of competencies in "Lifelong Learning", and "Individual and Team Work", these soft-skill attributes are examined in this study. Table 1 defines the chosen CEAB GAs according to the CEAB 2016 Accreditation Criteria and Procedures.

II. GRADUATE ATTRIBUTE DEVELOPMENT

As aforementioned, this course underwent significant blending of its seminar structure and some alterations were also made to better engage students within lecture times. Table 2 summarizes the changes made during the restructuring of ENGG 404 and the rationale for each. The manner in which the competency for each GA is developed by these various course components is explored in each sub-section.

TABLE 1

CEAB GAS AND DEFINITIONS [5]

CEAB GA	CEAB Definition
Professionalism	An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.
Ethics and equity	An ability to apply professional ethics, accountability, and equity.
Lifelong learning	An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge.
Individual and team work	An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.

A. *Professionalism*

Much of the course content deals with understanding the role of an engineer in managing risk and providing leadership with the intent to manage risks of operations and activities to acceptable levels in order to prevent loss incidents; thereby, protecting the public, environment, and business interests (protect assets and ensure safe, efficient, and reliable operations). This is delivered through lectures and online content, and reinforced by online quizzes, guided in-lecture peer-to-peer discussions, and case studies of past loss incidents. Guest presenters from government and industry provide a variety of perspectives to demonstrate risk management in practice, and to impart real life experience for the students on what they will encounter during their professional careers.

The team project requires students to apply course skills to an actual loss incident, and to take the role of a professional engineer to identify and apply the lessons learned. The team project emulates the real world wherein students take the leadership position in evaluating the case, formulating a strategy of recommendations, and advising their senior management. The instruction time and working time in the seminar allows students to receive guidance from experienced industrial professionals during this process. Much like in industry, students are also required to assess both themselves and their peers through the team self-evaluation and a semi-quantitative peer-to-peer assessment of team member effectiveness [7][8]. This self and peer assessment was conducted using the online Comprehensive Assessment of Team Member Effectiveness Peer Evaluation (CATME) tool.

B. *Ethics and Equity*

Ethics and equity is often the attribute that is least represented in a specific way in engineering education [3][9]. ENGG 404 explicitly instructs on ethics and equity by including discussions and examination on professional ethics, accountability, and equity. Through case studies, students are exposed to difficult questions surrounding ethics and equity, especially as it concerns accountability. Peer discussion and individual reflection help students explore how they will personally deal with these issues if or when they arise. A guest speaker from the Association of Professional Engineers and Geoscientists of Alberta (APEGA) solidifies this with an example of a past investigation into professional misconduct. The students' competency in this GA is assessed in the final exam as well as in the team project.

The team project is a key part of developing professionalism, ethics and equity throughout this course. According to ref. [10] graduates of university-level engineering programs often lack the skills required by employers, particularly the softer skills. To counter this notion, the team project emulates the collaborative environment of a typical professional workplace and requires the use (and development) of those skills required by professional engineers. There is an expectation for fair and equitable participation and contribution. Students are coached on what fair and equitable participation and contribution entails [7][8], and are held accountable for their individual performance through the CATME Peer Evaluation. These assessments may impact the grade of a student when substantiated through evidence and a fair and transparent process.

C. *Life-long Learning*

ENGG 404 promotes lifelong learning through having students take responsibility for their own learning, similar to expectations in the workplace. While this particular attribute is extremely hard to measure [3], the ENGG 404 instructional team emphasized this outcome throughout the course, often intertwined with those cases representing "Professionalism" and "Ethics and Equity" attributes. The blended learning format employed in this course places the onus on students to keep up with the out-of-lecture content; students must learn to be autonomous learners. In addition, the team self-evaluation report and the self-assessment conducted as part of the CATME assessment provide opportunities for the students to learn to identify their own areas of strength and areas where there is a need for improvement [7][8]. Also recall the "working styles survey" wherein the content not only describes how an individual "works", but also coaches an individual on how to work with others of the same or other working style [11].

D. *Individual and Team Work*

Several multifaceted components are employed in developing students' competence in both individual and team work. Individual students are responsible for their performance in, and completion of, online quizzes, assignments, and examinations designed to assess their understanding and application of the course content.

Specific courseware modules delivered in the instructional seminars and traditional lectures describe the team project parameters (e.g. the purpose and learning

TABLE 2: COURSE RESTRUCTURING AND REASONING

Course Component	Changes Made and Rationale
Courseware content	Some content remains delivered through traditional lectures. External resources were moved to online readings and videos, composed mainly of background information. Course content is continuously evolving, and significant additions were made to sections of the course discussing leadership from perspectives of effectiveness, accountability, professionalism, and ethics. Result: Opens face-to-face time for higher-level cognitive interactions, such as peer-to-peer discussion without increasing student workload.
Online quizzes	Introduced online quizzes related to upcoming or previously discussed course content as incentive for students to review online individual content and arrive prepared for in-class interactions. Result: Students are more prepared for in-class discussion.
Guided in-lecture peer-to-peer discussions	Increased amount of discussion time integrated within the traditional lectures. Result: Gives students more opportunity to apply course material to case studies, and develop skills used in the team project.
Instructional seminar time	Instructional time in the seminars was reduced to focus on the key points needed to complete the team project. Result: Provides more time for team-work with support of the instructional team members.
Working seminar time	Working time in the seminars was increased to focus on applying the skills in order to complete the team project. Result: Project progresses incrementally through-out the term.
Case studies	Background readings and videos are reviewed prior to class. Result: Allows for increased discussion, exploration, and application of concepts during scheduled time.
Online management of students' work	All individual assignments, team projects, mid-term examinations, and final examinations were converted from paper-based to on-line management. This includes: the assignment, the means to submit, and marking (for exams, a mix of automatic marking and "eyes and brain" marking). Benefits: facilitates managing larger enrollments, facilitates marking logistics (consistency and accuracy of marking, tracking marks), and eliminates paper.
Online "Working Style" assessments.	Replaced the in-seminar activity with an online activity. Result: Re-allocates seminar time towards the team project work.
Structured team creation process	Formalized a structured team selection process. Result: optimizes team creation, reduces time spent to assign teams, and teams kick-off upwards of 2 weeks earlier in the term.
Collaborative team projects (Technical Reports)	Changed the required components of the team project to remove a technical engineering assessment and focus on risk management from a leadership and organizational perspective. Implemented a rigorous and detailed marking rubric which facilitated assessment of work to a higher standard and a more uniform and consistent assessment across a team of markers.
Collaborative team projects (Peer Evaluation Strategies)	Scope of Team Self-Evaluation Reports reduced to critical points. Introduced use of online software to facilitate student preparation for discussion of collaboration and team work (CATME Peer Evaluation [4-6]), and to conduct peer-to-peer and self-assessments of performance on the team project. These assessments were also used to identify sub-standard and superior performers on the teams. Result: Objective assessment of peers.

outcomes of the project) and set clear expectations for individuals and the team, but also explore the concepts of individual and team effectiveness, collaboration, team dynamics, and team leadership (e.g. Tuckman's Models of Leadership and Stages of Team Development). The increase in segmented instruction time and supported work time in the seminars provides students an opportunity to contribute to a team, thus modelling the real world of the engineer, including dispute resolution, especially in managing expectations and under-performance within the team. Students have opportunities to practice roles and responsibilities as both a team member and team leader. A common but misguided approach to a team project is for the individuals to "divide the work, each person does their assigned work, then assemble into a completed project". Specific in-class demonstrations using course tools (root cause analysis, and creating a set of prioritized recommendations) contrast the process as applied by an individual versus that as applied by a collaborative team (or cooperative at the least). Whereas a person with a keen grasp of the root cause analysis is in a position to explain to their team-mates and lead the team through the process, this same person may not have the same grasp of the recommendations process and will be led through that process by another team-mate; the roles of being a team leader or a team-member change - leadership flows to the source of expertise. As would be expected of graduating engineers, it is relatively easy for team members to cooperate and coordinate throughout the project. Our aim is to further hone their collaborative skills – the cornerstone of high-performance teams

III. Research Methods

As part of course evolution, almost all components of the course delivery underwent revision. As previously mentioned, these revisions focused around developing the seminars into scaffolded working periods supported by the online and in-lecture content. These revisions were guided by those CEAB GAs that ENGG 404 was assigned to exemplify. For example, by increasing the amount of out-of-class content, and the variety of interactions with this content, the instructional team intended students to see the value of autonomous (or lifelong) learning. As our instructional decisions were guided by the CEAB GAs, the instructional team decided to investigate the question, "how might 'soft-skill' attributes manifest in a multifaceted engineering course?" by identifying those areas which both encouraged and measured CEAB GAs. These areas were primarily quantitatively investigated. Quantitative areas of measurement included assessment performances (i.e. individual assignments, midterm exams, final exams, and team project marks), instructional time allocation (i.e. use of face-to-face time for didactic lecture, practice time, or guided instruction), CATME ratings, and the results on a self-report, Likert-scale Blended Learning Survey, administered by the University of Alberta Centre for Teaching and Learning. These quantitative measurements were then reviewed in light of qualitative data, including anecdotal observations by instructors.

Using these metrics, the development of competencies in the four CEAB GAs under study in this paper were assessed. Not only can the development of competencies be directly measured using some of the above metrics, but also can be inferred through these metrics. For example, more time spent on the peer-to-peer discussion on the question "Is this ethical conduct?" may support the development of this competency.

IV. Results and Discussion

The restructuring of ENGG 404 resulted in some changes to the lecture and significant changes to the layout and requirements of the seminar time. Table 3 compares the resource allocation in both 2015 and 2016 in terms of time and personnel. The combination of increased enrollment (resulting in additional lecture and seminar sections) and the change to a heavily face-to-face discussion approach necessitated an instructional staff increase to two professors. The team increase was to ensure one professor available for every lecture and seminar and two teaching assistants (TAs) per seminar.

As recommended by ref [12], if the instructional team expected students to complete work before class, we should also provide some sort of reward. Hence, seminars were changed from instructor lectures to supported working time. Table 3 shows the significant increase in Team Project working time available to students with accessible guidance; 13.5 hours were made available in 2016 while the amount of formal instruction time was decreased. This resulted in a ratio of 1.5 times voluntary working time with guidance compared to mandatory instructional time in the seminars, providing significantly more time for development of teamwork competencies.

To accommodate the extra online work, mandatory seminar was reduced; this allowed for 2.5 hours of content to be moved to on-line assigned study, mainly videos and readings with associated quizzes. This online content also opened more time for students to discuss concepts and applications with their peers during the scheduled lecture time, with 7 to 8 hours of guided in-class peer-to-peer discussion. Another key anecdotal observation was that almost all teams continued to collaboratively work during the voluntary seminar times and built upwards of 10 to 15 hours of team-work; there were no such opportunities in prior years.

TABLE 3

Resource Allocation for ENGG 404 in 2015 and 2016

ENGG404 Time and Resource Allocation Per Term (to nearest 0.25 hr)										
Year	Metric	For Each **Lecture** Section (3 total)			For Each **Seminar** Section (3 total, various sizes)					
			Blended Learning							
		Total Lecture Time	On-line Assigned Study Time	Guided Peer-to-Peer Discussion Sessions (est.)	Maximum Allowable Mandatory Seminar Time (per Calendar)	Mandatory Instruction Seminar Time	Voluntary Working Time with Instruction Team Present	Out-of-class Requested Meeting Time with Prof.	Out-of-class Team Project Time (est.)	
2015	Time	41 hrs	0 hrs	3.5-4.5 hrs	16.25 hrs	13 hrs (80%)	0 hrs	10-20 hrs	10-30 hrs / team	
	People	1 prof.	None	1 prof.	1 prof.	1 prof.	None	1 prof.	None	
2016	Time	41 hrs	2.5 hrs	7-9.5 hrs (17-23%)	16.25 hrs	11.75 hrs (72%)	13.5 hrs	< 10 hrs	5-10 hrs / team	
	People	1 prof.	None	1 prof.	*1 prof. 1-2 TA's	*1 prof. 1-2 TA's	*1 prof. 1-2 TA's	1 prof.	None	

* 1, 2 or 3 instruction team members available per seminar depending on seminar size; 1 member per 10 to 15 teams.

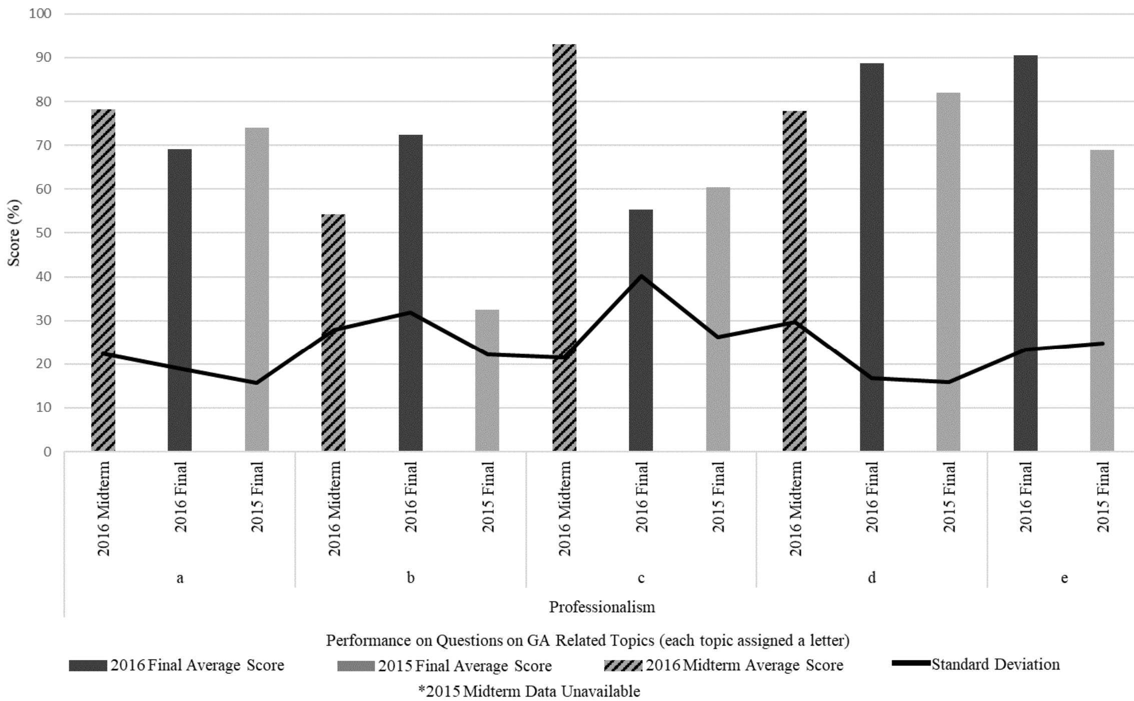

Figure 1: Performance on “Professionalism” Related Exam Question

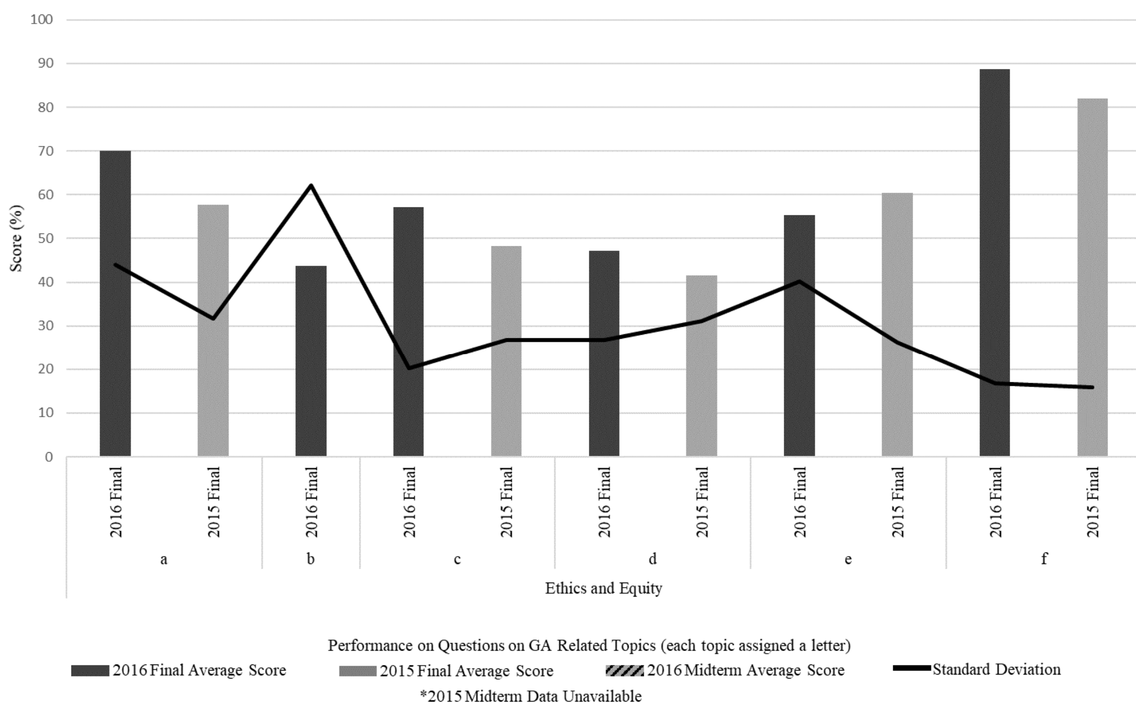

Figure 2: Performance on “Ethics and Equity” Related Exam Question

Figures 1-3 display a comparison of performance for all students on examination questions within topical areas that fall within the descriptions of the GAs of professionalism, ethics and equity, and lifelong learning from 2015 and 2016 (2015 midterm data unavailable). Each letter denotes a common topical area within a GA; each bar displays the average performance on all questions within each topical area. As shown in Fig. 1-3, generally students exposed to multifaceted learning components either performed similarly to or markedly better than students taught using only traditional lectures. A typical question on the final examination that assesses the competency of the student in "Ethics" requires the student to explain the meaning of "ethical conduct" using an example from their team project case study or their personal work experience. The student is guided in their response using a framework of questions shown in Table 4. The question is worth ten marks (the exam total is 165), with a detailed marking rubric; thus, the differentiation of students' performance category (unsatisfactory, developing, satisfactory, and excellent) is possible.

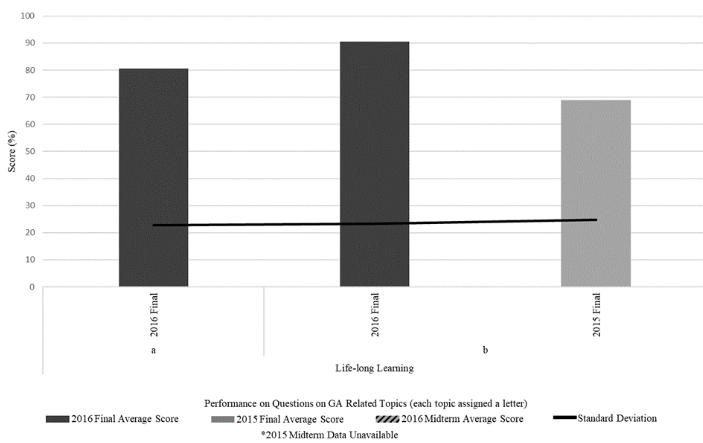

Figure 3: Performance on "Life-long Learning" Related Exam Question

TABLE 4

Typical Final Examination Question Assessing the GA "Ethics and Equity"

a) State your case study or workplace.

b) What is the situation or circumstance?

c) What is the issue or concern with that situation or circumstance in terms relative to ethical conduct?

d) What did you do (or what should you have done), again, in terms relative to ethical conduct?

e) What was (or would have been) the final result or outcome?

Weight: 10/165 marks on the final exam.

A. *Professionalism Observations*

Professionalism is a key requirement for a successful engineer; unfortunately, this is traditionally developed through the observation of and mentorship from practicing professionals once a student graduates and enters the workplace. ENGG 404 takes a two-stage approach to develop students' competency in professionalism. Firstly, students are educated on what the role of the professional engineer is through the course content and guest speakers that provide real world examples of their role. Secondly, students are asked to place themselves in the role of a professional engineer to successfully complete the team project. These two course components also allow for a quantifiable assessment of students' understanding and application of professionalism through their performance in the team project and on examinations. Usage of mid-term evaluations and final evaluations for both components allow instructors to assess competency development throughout the course.

Successfully completing the team project requires that the students' can perform the role of an engineer within the framework of a working team focused on delivering a product to a client (in this case, a loss incident report with analysis and recommendations). Despite the lack of a statistical difference between the Team Project Technical Report grades of the 2015 class and the senior students of the 2016 class shown in Table 5, instructors indicated higher quality submissions for the 2016 term. This slight decrease in averages may be due to the use of a more rigorous grading criteria. As the Technical Report is entirely based on simulating the role of a professional engineer, this indicates a strong level of competency in this GA.

The examinations assess students' understanding of the framework within which a professional engineer works, their role, and the application of this knowledge through scenario-based questions. Figure 1 summarizes the competency assessment of all students on topics falling within this GA through the medium of exam performance. It can be seen that student performance on these topics was generally either quite similar to or markedly improved when multifaceted learning components were employed (2016) as compared to traditional lectures alone (2015).

B. *Ethics and Equity Observations*

As mentioned in the literature, Ethics and Equity is often the most difficult attribute to instruct in a specific way and to measure [3][9]. In ENGG 404, it also proved difficult to measure students' level of competency developed on an ongoing basis. The instructional team endeavored to develop this GA with discovering how decisions are made: decisions are based on the values held by an individual. On this basis, students are posed several situations, followed by an opportunity for peer-to-peer discussion. Situations include: the behavior upon finding a five-dollar bill; the search warrant actually served by an investigator of the Minister of the Environment and the discovery in the filing cabinet; your hypothetical position at a well-services company and the “better-than-expected” results of a well survey; and the actual investigation of an environmental engineer at BP Energy after the BP-Macondo / Deepwater Horizon loss incident. Students were also exposed to the lessons of the broadly known Milgram experiment that demonstrates the importance of the position of authority in decision making and directing subordinates. The blended learning format includes: prior to attending a seminar focused on Ethics and Equity, students were tasked with watching videos about the Milgram experiment and completing a short quiz. In each of these situations, students are astonished by the situations in which they may find themselves, and several have raised possible situations themselves e.g. “What if I owned a few thousand dollars of shares or had my entire life savings invested? What should I do?”

The competency level of this GA is quantitatively assessed on the final examination. A series of questions guides the student to explore a situation from their actual work experience or their loss incident case study. As shown by Figure 2, students in the 2016 year tended to score higher on those questions about Ethics and Equity than students within the 2015 course offering. As many of these questions are the same on both exams, it can be seen that students in the 2016 offering of ENGG 404 did, indeed, achieve a higher level of comprehension of this GA than those students in the 2015 course. In addition to this, students scored an average of 90% on the question about the ethical responsibility of those in authority in the blended learning quiz about the Milgram experiment. With this evidence, and the increase in student discussion time, we can conclude that this (often difficult to implement and measure) attribute has been effectively developed in ENGG 404.

C. Life-long Learning Observations

Structure and content of ENGG 404 readily lends itself to developing lifelong learning skills. The use of the case study teaching format supplemented with guided peer-to-peer discussion develops basic skills for lifelong learning such as critical thinking and meaningful question formulation e.g. probing questions. The guided discussions help students learn to identify knowledge gaps (i.e. what information is missing, confusing, or conflicting?), identify potential sources of information including themselves (i.e. can this missing information be obtained using their or others’ technical knowledge to surmise possible circumstances and conditions?), critically evaluate information and opinions obtained from peers by using the tools and methodologies taught in this course, and then re-view and revise their solution.

This process is extensively used in the case study of the Nypro Works, Flixborough, U.K. loss incident. The two key lessons of “know your limits” and “ask for help” are part of a strong foundation for identifying knowledge gaps and how to address those gaps. In 2016, 15 min. of online activity and an entire 50 min. lecture is devoted to this case study; approximately half of this lecture period is spent in guided peer-to-peer discussion sessions, and 5 min. of video is reviewed to highlight key concepts. In contrast, in 2015, while a 50 minute lecture was also used, 15 to 20 minutes was spent watching a video that was not available ahead of time. Only 6 min. was available for guided peer-to-peer discussion.

ENGG 404 also develops competencies in lifelong learning by having students conduct self-exploration and self-assessments of their team “working style” and performance. The working styles assessment has students explore their team work preferences, and how this affects their means and ability to communicate and work with others. Two categories, “Expecting Quality” and “Having Relevant Knowledge, Skills, and Abilities”, of the CATME Peer Evaluation tool, have students perform both self-assessments and peer-assessments on their knowledge base and understanding of sufficient quality work, and have students continue to practice these assessment skills at the end of the course. Table 5 reveals that >95% of students in the 2016 term received a self- and peer-assessed score corresponding to the minimum performance of a successful team member in these categories (score of 3 or greater). The ability for a student to understand their working style and how best to work with others is a fundamental adaptation skill in a corporate team; thus, a life-long learning skill. A successful blended learning course is contingent upon student’s being accountable for their own learning and therefore develops competency in managing their own learning [2]. ENGG 404 instructors observed an increase in the number and quality of insightful questions on the field of risk management expertise compared to previous years. It is interesting to note that 38% of respondents to the Blended Learning Survey indicated completing the readings to the recommended schedule, while 82% of respondents indicated completing the assigned online activities; these included videos that were not graded, and quizzes, completion of which were 5% of the overall course grade.

TABLE 5

ENGG 404 Senior Student Performance

Year	2015	2016
Teams	47	61
Format	Traditional	Blended
Assessment (Avg. ± St. Dev.)		
Assign. 1 Grade	73.1 ± 15.4	71.0 ± 16.1
Assign. 2 Grade	72.8 ± 19.3	74.1 ± 13.9
Midterm Exam Grade	76.6 ± 13.0	74.9 ± 9.3
Final Exam Grade	62.1 ± 9.8	69.0 ± 8.4
Team Project Technical Report	83.0 ± 9.2	80.7 ± 5.1

Throughout the term, ENGG 404 students are expected to grow as autonomous learners and encouraged to do this through peer discussion, blended learning, and both self- and peer-assessments. The competency of lifelong learning is developed starting with the fundamental components the workers' competency level in a skill, and their attitudes as their competency develops. As shown in Figure 3, students in the 2016 offering of ENGG 404 scored much higher (approximate increase of 20% in the average) on this question. It is clear, students are not only offered chances to develop their lifelong learning skills, but are able to better comprehend what these skills entail for their careers as engineers.

Most recently, the competency of lifelong learning is further developed using a broad base comparison of two types of vehicles, one powered by an internal combustion engine and another by an electric motor. The comparison spans many upstream and downstream segments such as: the source of raw materials, the source of energy, the discharge of waste materials to the environment, and ultimately the end-of-life disposal of the two vehicles. The comparison is by no means quantitative in any respect, yet does train the students to examine comparisons, to formulate qualitative questions that lead to quantitative questions and ultimately quantitative data, and quantitative data leading to informed decisions. The exploration of this comparison is essentially 50 minutes of open-ended questions to the students with interspersed opportunities for peer-to-peer discussion thus making for a lively and dynamic class learning experience. The development of this competency is formally assessed on the final exam by posing a simple comparison of several paired everyday items e.g. ceramic reusable cups at one well-known franchise fast food chain versus one-use disposable cups at another. This formal assessment was first applied in the 2016 final exam; thus, a comparison in change in competency development with application of blended learning can be made. It can be said that the desirable approach to apply blended learning techniques in this course did result in the formalization of this interactive lecture and assessment on the final exam.

D. Individual and Team Work Observations

In addition to the previously discussed individual performance assessments (i.e. assignments, blended learning quizzes, assignments, and final exams), further development of individual and teamwork competencies, specifically teamwork skills, were observed through taking a closer look at some of the Team Project components. The Team Project approach is intended to develop competencies in individual work towards the team's objectives, in teamwork towards collaboration with team members, and in leading team members in a team effort; each of these skills are formally taught within the course of ENGG 404 and can be found in the mandatory courseware [5]. The Team Self-Evaluation Report is one component of the team project where this is found. The quantitative measurement on this report (i.e. student grade) does not measure the level of competency development; rather the report is intended as a tool for self-exploration of the skills necessary to develop the competencies in teamwork (lifelong learning applied to team work). The Team Self-Evaluation Report captures:

- The team experience in leadership style and stage of team development as the team evolves.
- The development of the 7 skills of effective team members: cooperation, coordination, communication, comforting, conflict resolution, cohesion, and collaboration.
- The development and performance of the team in 5 key team processes: managing information, leveraging expertise and skills, distribution of tasks, project controls, and the decision-making process.
- The assessment of each team member using the CATME peer evaluation tool on five characteristics: Contributing to the Teams' Work; Interacting with Teammates; Keeping the Team on Track; Expecting Quality; Having Relevant Knowledge, Skills, and Abilities

The results of the CATME Peer Evaluation tool in Table 5 indicate the levels of competency at the end of the course in both individual and team performance. While the two previously discussed categories of "Expecting Quality" and "Having Relevant Knowledge, Skills, and Abilities" are relevant to individual learning, they also apply to a team setting. The same assessment skills discussed in lifelong learning are further developed by applying them to the self- and peer-assessment of critical teamwork categories. The CATME Peer Evaluation statistics indicate that most students self- and peer-assess their competencies in the range mid-three to a high-four on a five-point scale; in most categories, over 90% of students meet or exceed what the authors consider the minimum performance for a successful team member. As students are informed of what characteristics an effective team member exhibits and an extremely high number of students achieve these measures, it can be assumed that the GA, and nuanced skill, of teamwork is being successfully developed while students are also expected to complete individual work throughout the course.

E. Data Limitations

Several factors make it difficult to make meaningful comparisons between the 2015 student performance and the 2016 student performance. The first confounding factor is the comparison of the year-over-year results is the change in demographics of the enrolled students. Specifically, in the 2015 Fall academic term and all terms prior to it, ENGG 404 was restricted to those in their final year of study. Starting with the 2016 Fall academic term, the course was opened to students in as early as their first term of the second year for certain disciplines. The second factor confounding comparisons is the introduction of a larger marking team than used in previous years when marking the team projects. Rather than a single instructor, the marking team consisted of two instructors and two teaching assistants. This necessitated the creation of a detailed marking rubric to promote inter-marker reliability. This detailed rubric also resulted in a higher standard of assessment applied to the team project technical report. For these reasons, Table 6 only compares senior student performance in five activities: the two assignments, the midterm examination, the final examination, and the Team Project Technical Report. The comparison of the total course grade is not a valid metric due to component weighting redistribution conducted as part of the course evolution. As can be seen, student performance under the traditional teaching format and the blended learning format was similar when comparing averages and standard deviation overlap. Despite the slight fall in most assessments, 43% of respondents to the Blended Learning Survey agreed or strongly agreed that this course improved their understanding of key concepts (31% of respondents were neutral). In addition, the data demonstrates that course quality in terms of academic achievement did not suffer with the significant expansion in class size.

TABLE 6

CATME Peer Evaluation Results from ENGG 404 (2016) [7][8]

	CATME Score Average ± St. Dev. (Out of 5)	**% of Students Scoring < 3**
Contributing to the Teams' Work	4.2 ± 0.75	5.1%
Interacting with Teammates	4.28 ± 0.62	3.4%
Keeping the Team on Track	4.12 ± 0.80	9.3%
Expecting Quality	4.22 ± 0.66	3.8%
Having Relevant Knowledge, Skills, and Abilities	4.32 ± 0.64	4.2%

One key anecdotal observation not reflected in the assessment data is the progress and completion of the team project throughout the term. The extent of completion was greater in the new format versus previous years. In previous course iterations, students often waited until the last week or two prior to the due date to complete the project; in the new format, teams steadily progressed through sections of their project, minimizing the last-minute completion rate. The formative assessment of all team projects two weeks and one week prior to the due date clearly revealed that all teams were better than 80%, some near completion, versus a historical "cram completion" of the project. About one-fifth of the teams completed and submitted the project several days ahead of the due date, something rarely observed within previous course offerings.

Finally, the effect of the change on student marks from paper based examinations to secured workstations for online examinations, resulting in changes to both delivery format and surroundings, has not and cannot be isolated in this study, except to say there was no statistical difference in the distribution of marks. Having said this, the ability to maintain the final examination quality and security, and marking the final examination with reasonable resources in a reasonable time-frame (under 40 grading hours for ~240 final exam papers) was achieved versus the prior paper-based process.

V. CONCLUSION

We contend that the utilization of the multifaceted instruction techniques offered by blended learning improve the development of student competencies in the "soft-skill" GAs of professionalism, ethics and equity, lifelong learning, and individual and team work, as evidenced in this study. In concert with the implementation of blended learning, our objective was also to, at minimum, maintain the quality of the course delivery and the student learning experience, while addressing the challenge of significantly increased enrollment. As presented by data and discussion, the students in a multifaceted, blended offering of ENGG 404 are further developing their competency in those GAs under investigation than those students in previously, primarily didactic, offered sections of this course. As these courses grow in numbers, we have assured that a blended learning format will maintain the integrity of GA development in our undergraduate engineering students.

A potentially fruitful area for future work could be to analyze student beliefs on GA development in this course using the blended format. Preliminary data is available but further study would be warranted. Investigation of alignment of student beliefs and instructor perception may provide useful insights.

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