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Enhancing Student Engagement with Introductory Engineering Ethics Using a Blended Approach of Microlearning and Case Studies

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ABSRACT

A new blended learning module was developed and delivered to all first-year engineering students in an introductory engineering concepts course at the University of Guelph. In previous years, engineering ethics was introduced to first year students in a traditional manner through lectures and textbook readings. The new blended approach to engineering ethics included six microlearning modules, an in-class case study seminar, and an evaluation of student learning through a ethics quiz. The microlearning component involved short online ethics videos featuring undergraduate students, followed by online assessments to reinforce information retention. The content covered introductory ethical principles and the application of ethics and professional ethics to ethical dilemmas. After completing the microlearning modules, the in-class workshop directed students to work together in teams to evaluate an ethical case study. The case study was designed to supplement applicative learning gained using the online medium. Following the team case study, a quiz containing multiple choice ethics questions and a long answer case study was used to assess each student's individual knowledge on engineering ethics. This paper investigates the ability to enhance the student's learning experience of professional skills such as engineering ethics by using a blended style of independent tasks and a peer-learning activity. Specifically, this paper investigates three main questions:

1. *Does microlearning increase student engagement?*
2. *Does increased engagement result in higher performance on ethics assessments?*
3. *Is a blended approach of independent microlearning and an in-class team case study effective in bridging the lower order of memorizing ethical terms to applying ethical principles to a dilemma?*

The question on engagement was evaluated through an end of semester Likert style survey, and the impact of the learning approach was assessed by comparing student participation in the microlearning modules to performance in an end of semester ethics quiz. The Likert survey responses suggested that students enjoyed the microlearning module and were engaged with the content. Based on the data collected and the analysis conducted, it was concluded that there was a positive impact on teaching professional ethics to using the blended learning approach through an online microlearning module and a team case study. The blended microlearning and case study methodology appears to be an effective approach for professional skill development such as engineering ethics, and the methodology continues to be utilized in the introductory first-year engineering course at the University of Guelph.

INTRODUCTION

The University of Guelph (UofG), the School of Engineering (SOE) offers seven engineering programs: biological, biomedical, computer, engineering systems & computing, environmental, mechanical and water resources. Incoming students also have the option to pursue an engineering degree without declaring a major for the first few semesters of their education. All first-year undergraduate engineering students are required to take ENGG*1100 – Engineering and Design I, an introductory course to engineering design and the engineering profession. In the fall of 2019, there were 381 engineering students registered in the course. Historically, it has been a challenge

to engage students in professional skills topics such as engineering ethics due to the competing activities of the design aspects of the course. To increase student engagement and learning without excessive demands on their classroom time, microlearning techniques were employed to support in-class activities and provide a blended learning experience. The principles of engineering ethics were taught using a microlearning approach in the form of six weekly online independent learning modules. These modules consisted of short learning videos, and a short, formative assessment designed to reinforce the concepts covered. The assessment consisted of multiple choice, multiple select, and true/false questions that allowed the students to receive feedback on their understanding of the subject. After the six weeks of microlearning, an online formative assessment which covered all six ethics topics was made available to the students for unlimited practice purposes. In the design lab after week six, students worked as a team in their design groups to evaluate an engineering ethics case study to supplement their online learning. The final component of this blended learning series of activities was an evaluation of student knowledge. Each student wrote a quiz containing multiple choice ethics questions and a long answer case study evaluation to assess their individual knowledge of engineering ethics.

This paper will investigate three main questions:

1. Does microlearning increase student engagement?
2. Does increased engagement result in higher performance on ethics assessments?
3. Is a blended approach of independent microlearning and an in-class team case study, effective in bridging the lower order of memorizing ethical terms to applying ethical principles to a dilemma?

Communicating the importance of social skills to incoming students is difficult as they often have an expectation that the focus of engineering education is solely the development of strong technical skills. Historically, a strong technical background was the main requirement when hiring engineering graduates due to the fast development of technology [1]. More recently, there has been a growing demand for better-rounded graduating engineers with well-developed professional skills – often referred to as soft skills [2]. It is difficult to intentionally teach professional skills in engineering studies, as students and faculty typically prioritize the technical aspect of their degree [3]. This often leads to mediocre performance in a working environment despite the students' education. Thus, it is imperative to teach professional skills to students.

Ethics is a professional skill that holds great importance for engineers and is evaluated for the professional engineer designation [4]. During their engineering studies, students are often not deeply exposed to ethical constructs until their final year. This can result in students designing products and projects without considering the ethical implications their creations may have. Therefore, a module focused on the relevance of ethics to engineering was developed for incoming first-year students to expose them to ethical frameworks.

LITERATURE REVIEW

In traditional settings of large lecture halls, students often reach content capacity and little interaction between the information and learner occurs [5]. On the other hand, microlearning focuses on short-term learning tasks, allowing students time to internalize new content [6]. Providing small amounts of information when the student is willing to learn, overcomes information overload [7]. One definition of microlearning is "*an instructional unit that provides a short engagement in an activity intentionally designed to elicit a specific outcome from the participant*" [8]. Microlearning is most notably used in corporate environments, however recent

educational studies have shown evidence of an increase in academic achievement by up to 18% [9]. Social and behavioural changes in the current generation of students is no doubt shaped by the influence of the internet, social media, and smartphones. Microlearning can mimic the fast-paced google search learning, millennials and subsequent generations are conducting, creating a more relatable workspace, as well as accommodating for decreasing attention spans [10]. These practices of presenting quick information are also used as marketing strategies, where average customers' attentions have decreased from 30 seconds, to 6 seconds [11]. Videos cater to multisensory learning and gives the audience more than one way to relate to new information, allowing for greater comprehension compared to reading text alone [12]. Therefore, the use of microlearning in the form of short videos may provide an alternative learning procedure to typical hour or longer lectures.

Although microlearning has many benefits and application, it does not provide an all-encompassing educational experience, as it is good for declarative knowledge but fails to encourage critical thinking [8]. It is however accepted that learning in small parts can better engage students in blended learning settings [13]. A blend of online and in-class learning has been found to reduce dropout rates and improve exam marks [14]. As well, in-class problem solving coupled with online video assignments, has been found to increase student satisfaction and attendance [14]. A study using veterinary students found improved ability to communicate their work when given peer-to-peer feedback [15]. Likewise, if first year engineering students were capable of working collaboratively, they would have relatively higher academic achievement to those that did not [16]. Thus, the module was created with a largely online component and an in-class case study to analyze within groups of peers.

In general, it is essential for students to identify the importance and relevance of the content being taught to keep them engaged [7]. From a professional standpoint, engineering ethical issues are often integrated with technical problems, and students need to comprehend the weight of their actions as an engineer [17]. From a teaching standpoint, engineering students' learning is focused on the design process, following the steps of identifying the problem, constraints, brainstorming options, developing design alternatives, selecting a final design, refining this design, and then implementing it [18]. These steps are reinforced throughout the curriculum and can be applied to ethical dilemmas. For instance, a general ethical decision-making process would include identifying the relevant moral factors, and conflicting moral responsibilities, creating alternate courses of action, and then implementing the final decision [18]. The parallels in critical thinking can be drawn from the design process and are highlighted for students to encourage active participation. These key skills that require a higher degree of depth and expertise cannot be taught through microlearning alone, and must be supplemented in other forms of learning activities [8].

For a professional engineer, the greatest difficulty in dealing with ethical problems is there are often multiple solutions [17]. The goal of the module is to have the students evaluate the best choice in an engineering context using the Professional Engineers Ontario (PEO) Code of Ethics [19]. The introduction of moral theory, leading into codes of ethics and case studies, has become a prominent curriculum framework for teaching engineering ethics to students since the end of the 20^{th} century [20]. A common challenge faculty are faced with, is a lack of interest in the content among students [21]. It is imperative that the module address emotional engagement, intellectual engagement and guideline knowledge [17]. In other words, students needed to be willing to invest themselves into making ethical decisions, understand how to make ethical decisions, and know what guidelines they follow as professional engineers – in this context the PEO Code of Ethics. To fully develop the professional skill of ethical competency, a blended learning module was

implemented with a focus on engaging students with content outside of the traditional lecture setting, then applying what they have learned in a peer-to-peer activity.

METHODOLOGY

Effective microlearning must assess the learner before progressing to the next unit and a high level of organization is required when presenting the topics [7]. At the University of Guelph, each semester has 12 weeks of classes. Introductory engineering ethics principals were taught in parallel to the rest of the course content throughout the fall 2019 semester, using a microlearning component consisting of a series of six online instructional videos. After each video, the student completed a formative quiz assessment designed to provide feedback on their understanding of the topic. The learning goals for the module were determined before developing the content and organization of the topics. These learning goals were to:

- define the fundamentals of ethics introduced;
- define and recognize the significance of ethics in the engineering profession;
- distinguish between personal ethics vs. professional ethics;
- analyze unethical situations using the PEO Code of Ethics; and
- select and justify the most ethical decision in an ethical dilemma using an ethical decision-making model

Module Development

The content presented was based primarily on material in "*Introduction to Professional Engineering in Canada, 5th ed.*" [22]. This includes basic topics of general ethics, ethical frameworks, professional engineering ethics, professional engineering seal/iron ring, unethical situations and ethical decision making. The timeline and topics for the module are outlined below in Table 1. Important terms are defined in Table 2.

Table 1: Introductory engineering ethics module and recommended activities breakdown for fall 2019 semester.

Week	*Delivery Format*	*Topic*	*Action*
2	Online	1.0 General Ethics: • Values, Morals, Ethics • Dilemma • Moral minimalism • UBC Venn diagram • Equity, Diversity, Inclusivity	Complete Topic 1– General Ethics videos Topic 1 Quiz – online formative
3	Online	2.0 Ethical Frameworks: • Normative • Duty • Rights/justice/fairness • Utilitarianism	Complete Topic 2 – Ethical Frameworks videos Topic 2 Quiz – online formative
4	Online	3.0 Professional Engineering Ethics: • Personal ethics vs. professional ethics • The National Code of Ethics • PEO Code of Ethics • P.Eng ethics exam	Complete Topic 3 – Professional Engineering Ethics videos Topic 3 Quiz – online formative
5	Online	4.0 P.Eng Seal and Iron Ring: • Quebec bridge	Complete Topic 4 – P.Eng Seal and Iron Ring videos

		• The Ritual of Calling of Engineer • What the seal is • When to use the seal	Topic 4 Quiz – online formative
6	Online	5.0 Unethical Situations: • Intellectual property (plagiarism) • Whistleblowing • Recognizing unethical situations • Victim determination	Complete Topic 5 – Unethical Situations videos Topic 5 Quiz – online formative
7	Online	6.0 Ethical Decision Making: • Parallels to design • ASIDE • Event Tree • Case studies	Complete Topic 6 – Ethical Decision-Making videos Topic 6 Quiz – online formative Practice Quiz – online formative
8	In-class	Team Case Study	In-lab Case Study (1%)
9	In-class	Final Individual Quiz • MC Quiz • ASIDE Quiz	In-lab Quiz – Summative (4%)

Table 2: Important terms.

Term	***Definition***
Microlearning Component	The entire online microlearning component of the module, including all 6 topics.
Module	Inclusive of the entire blended learning experience including the microlearning series, team case study, practice quiz, final individual quiz, single in-class lecture, and optional readings.
Topic Quiz	10-question online formative quiz covering the module topics, each containing 3 true/false, 2 multiple-select, and 5 multiple choice questions. Students had unlimited attempts to independently complete each topic quiz..
Practice Quiz	An online quiz, made available after week 6, containing 10 questions randomly selected from a pool of 120 questions related to the topic quizzes. Students were able to repeat this quiz, generating a new quiz each time.
Final Individual Quiz	The final quiz of the ethics module completed in-class by students under supervision. The quiz had two sections: MC Quiz and ASIDE Quiz.
MC Quiz	The multiple-choice portion of the final individual quiz.
ASIDE Quiz	The long answer, applicative case study portion of the final individual quiz.
Team Case Study	The only in-class activity related to the ethics module, where students applied the ethical dilemma model in a team under supervision. Solutions were reviewed with the class at the end of the session.

The online module was split into 6 topics each having 4-5 short videos and 10 question topic quizzes. The videos ranged between a duration of 0.5-2.5 minutes, while all 6 topic quizzes consisted of multiple choice, multiple selection and true false questions. The cumulative practice quiz was 10 questions selected randomly from a pool of questions from the past 6 topic quizzes and an extra set of problems. The microlearning component was also supplemented by recommended readings and in-class lecture material. Although a guideline was provided to the students, they were not required to finish the formative quizzes within the assigned week. This allowed students to work on the microlearning component when they wanted to, thereby maximizing engagement. Microlearning techniques are limited to teaching knowledge-based concepts, and have little ability in teaching applicative approaches [23]. Therefore, the module required a bridging activity to create that application opportunity. In ENGG*1100, the students are assigned to teams at the beginning of the semester for their final design project. To leverage team

development, while also providing supplementary learning, a team ethical case study is assigned during their lab component in week 8 of the semester. The team case study created an opportunity for students to practice applying critical thinking to ethical case studies using decision-making modelling they had learned in the online microlearning component. This activity was assigned 1% of the students' final grade to motivate them to participate.

The following final individual quiz evaluation was assigned 4% and completed in the following week's lab. The main objective of the final quiz was to assess the student's learning and the depth of their ethical analysis. The first 10 questions were multiple choice created partly from the formative quizzes and partly from additional questions created for the final practice quiz. The second part was a case study meant to be analyzed using the ethical decision-making model, ASIDE, which was introduced online and practiced in class with their team members.

ASIDE Model

As part of the ethics module, an ethical framework called the "ASIDE" (Action, Stakeholders, Information, Diagram (event tree), and Evaluate) model was introduced. *This model was adopted from Introduction to Professional Engineering in Canada, 5th edition, by Andrews et.al (2018)* [22] and labelled 'ASIDE' as an easy to remember acronym. It is a method that can be used to evaluate a potentially unethical situation and build awareness regarding the impact professional engineers can make. The primary goal of the case studies in this introductory module is for students to utilize the ASIDE model as a thinking framework for engaging with ethical dilemmas, and to learn the language surrounding engineering ethics. These foundational elements are important for students to be able to assess ethical dilemmas in more than a superficial manner. As a result, the cases in these early stages may not present the full complexity that might emerge in professional engineering. Students can build on their experience by using the model for more complex cases in upcoming years. An example of a case study is provided below with the ASIDE evaluation and solution provided in Table 3.

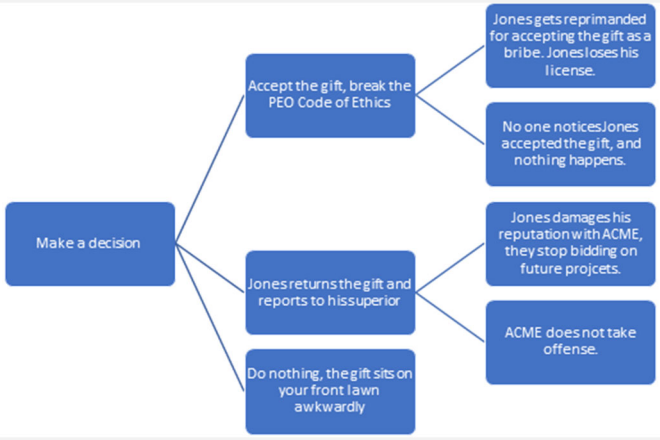
***C**ase study example*

The case study below is taken from page 54 of *Introduction to Professional Engineering in Canada (Fifth Edition)* by Andrews *et al (2018)* [22]

> "John Jones is a professional engineer who works in the engineering department for a medium-sized Canadian city. He has been assigned to monitor and approve, on behalf of the city, each stage of the construction of a new sewage treatment plant, since he was involved in preparing the specifications for the plant. The contract for construction has been awarded, after a competitive bidding process, to the ACME Construction Company. About ten days before construction is to begin, he finds a gift-wrapped case of rye whiskey on his doorstep, worth an approximate value of $600. The card attached to the box says, "Looking forward to a good professional relationship," and is signed by the president of ACME Construction".

Table 3 Expectation set for how students were to analyze ethical case studies.

ASIDE Component	***Answer***
Action *– How is this situation unethical, and does it require attention?*	You cannot participate in actions that can potentially affect the integrity of your work like accepting gifts from vendors.
Stakeholders *– Who are the stakeholders and their interests?*	John Jones – do job, accept gift President of ACME – maintain relationship with client Medium Canadian city – get a new sewage plant

Information *– What are the details of this situation?*	John Jones is a P.Eng that is obligated to act ethically. He received a bribe from a bidder suggesting he act in their favour in the future which would be unfair to other companies within the next bidding process.
Diagram *– Create an event tree of the possible actions that can be taken and their consequences.*	
Evaluate *– Pick an action from your event tree and justify based on the PEO Code of Ethics and general ethical principles.*	Jones should not accept the gift because he would be breaking the third clause of the PEO Code of Ethics, "devotion to high ideals of personal honour and professional integrity." Jones' duty to his employer can be compromised due to the gift, so accepting would be a conflict of interest.

Student Feedback Survey

At the end of the semester, an anonymous feedback survey was provided to students to assess their interpretation of the ethics module delivery, module understanding, and feedback. The questions were used for student feedback and split into categories as listed in Table 4. To analyse the effectiveness of the blended learning, it was essential to assess student opinion on module delivery, and module understanding as these two need to be accomplished for any sort of engagement to occur. Some questions had an open response, while others were on a 5-point Likert scale (ranging from "strongly disagree" to "strongly agree"). The questions were designed to see if students enjoyed the module, and their confidence in their knowledge. The survey was voluntary, anonymous, and without compensation to encourage honest answers. Interpreting whether the students had positive or negative opinions towards the microlearning module is important for future improvements as microlearning thrives in environments where students are willing to participate.

Table 4: Questions in the student feedback survey on the ethical module.

Question 1: Ethics Module Delivery (Likert Scale)	
Ref. #	**Statement**
1	I found the microlearning ethics module enjoyable to complete.
2	I found the videos in the ethics module to be engaging.
3	I feel confident in my knowledge of introductory engineering ethics.
4	I would recommend that the ethics module continue next year.
5	I like the microlearning-style better than the traditional lecture style.
6	I feel I had to watch the videos multiple times to fully retain the content.
7	I would have spent more time studying the ethics content if it was taught in the traditional lecture style.
8	I feel microlearning was a suitable platform for teaching ethics.
9	I found the team case study was helpful in bridging the gap between what I learned from the ethics module videos and applying the ASIDE model.
10	The ethics module was well organized.

Question 2: Module Understanding (Likert Scale)	
Ref. #	**Statement**
11	I can confidently compare different options from an event tree and determine the more morally just option.
12	I can interpret why a situation is unethical and what makes it a dilemma.
13	I can apply the PEO Code of Ethics to an ethical dilemma.
14	I can distinguish between my personal and professional ethics.
15	Through this module, I have greatly increased my knowledge of introductory engineering ethics.
16	I can define the letters of ASIDE.
17	I recognize the significance of ethics in the engineering profession.
18	I can define basic ethical terms like: values, morals, dilemma, moral minimalism, etc.
19	I know the requirements for attaining the P.Eng. status.
20	I feel confident determining stakeholders and their objectives in an ethical dilemma.
21	I can select and justify an ethical decision for a dilemma using ASIDE and the PEO Code of Ethics.
22	I can define microlearning.
23	I feel ethical judgement is just as important as technical skills for engineers.

Question 3: Long Answer (Open-ended)	
Ref. #	**Statement**
24	What aspects of the ethics module were most valuable to you?

Question 4: Long Answer (Open-ended)	
Ref. #	**Statement**
25	What aspects of the ethics module were least valuable to you?

Question 5: Long Answer (Open-ended)	
Ref. #	**Statement**
26	What recommendations do you have for enhancing the ethics module?

RESULTS & ANALYSIS

Of the 381 students enrolled in ENGG*1100 during the fall of 2019, 192 completed the entire engineering ethics blended learning module including attempting all topic quizzes, writing the practice quiz, participating in the team case study, and writing the final individual quiz. A further 176 students participated but did not complete all components. 368 students wrote the final individual quiz and of these, only 3 did not do any other ethics components. Table 5 provides a distribution of class participation in the engineering ethics blended learning module.

Table 5: Distribution of class participation

Engineering Ethics Module Components Completed	**Number of Students**	
Final Quiz + All Topic Quizzes + Practice Quiz + Team Case Study	192	
Final Quiz + Some Topic Quizzes + Practice Quiz + Team Case Study	43	
Final Quiz + No Topic Quizzes + Practice Quiz + Team Case Study	15	
	Subtotal	**250**
Final Quiz + All Topic Quizzes + Practice Quiz + No Team Case Study	15	
Final Quiz + Some Topic Quizzes + Practice Quiz + No Team Case Study	7	

Final Quiz + No Topic Quizzes + Practice Quiz + No Team Case Study	2	
	Subtotal	**24**
Final Quiz + All Topic Quizzes + No Practice Quiz + Team Case Study	27	
Final Quiz + Some Topic Quizzes + No Practice Quiz + Team Case Study	31	
Final Quiz + No Topic Quizzes + No Practice Quiz + Team Case Study	25	
	Subtotal	**83**
Final Quiz + All Topic Quizzes + No Practice Quiz + No Team Case Study	3	
Final Quiz + Some Topic Quizzes + No Practice Quiz + No Team Case Study	5	
Final Quiz + No Topic Quizzes + No Practice Quiz + No Team Case Study	3	
	Subtotal	**11**
No Final Quiz	13	
	Subtotal	**13**
	Total	**381**

Survey responses and student involvement with the online module were used to measure engagement with the content, while final quiz grades were used to measure student performance. A blended approach of microlearning and peer-to-peer case study practice was used to provide a more rounded learning plan, aimed to develop both conceptual knowledge of introductory ethics and applicative skills in recognizing an ethical situation and how to resolve it. Whether this blended approach was beneficial to the learning of students is also evaluated based on attendance and final quiz grade performance. Investigating the students' engagement and their ability to apply the ASIDE model will be indicated using student survey responses and completion of topic and practice quizzes. Performance will be determined using the grades from the multiple choice (MC) portion and the case study (ASIDE) portion of the final quiz.

Student Engagement

Maintaining student engagement in large class sizes is a common hurdle for first year introductory courses. Adopting the microlearning module allowed students to work at their own pace and personalize their learning environment. At the end of the semester, the students were asked to complete an anonymous survey that focused on their impression of the ethics module including its delivery, their understanding, and their overall feedback. The survey was voluntary with no compensation and resulted in 62 responses, or 17% of the students who completed the final quiz.

Survey Question 1: Ethics Module Delivery

To maintain interest in the content, microlearning depends on a high degree of organization of the modules and on willing participants. Thus, the students' interpretation on the delivery and the activities conducted is important for scaling their engagement with the topics. The responses to the Likert scale questions on module delivery are presented in Figure 1.

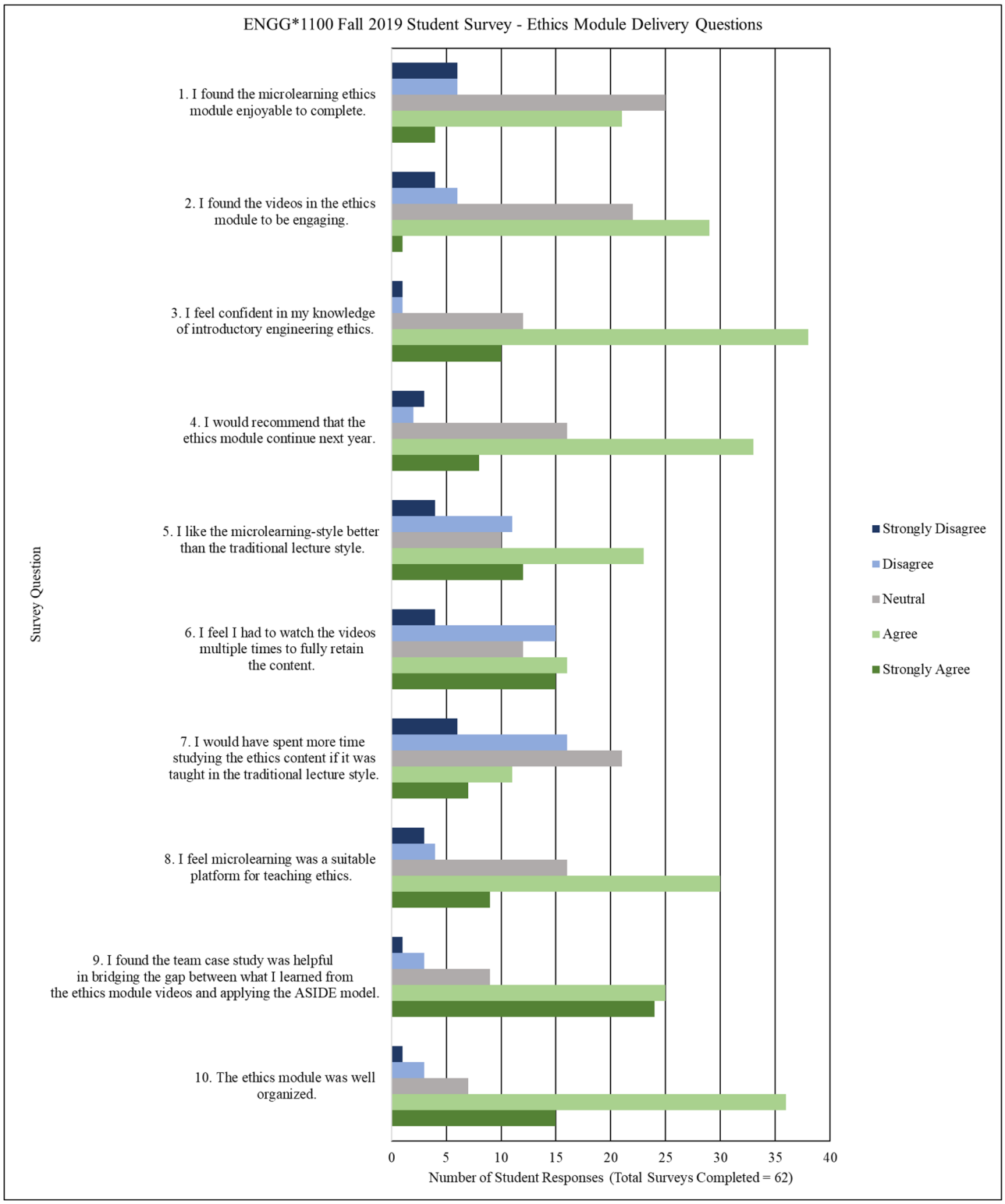


Figure 1: Likert scale opinions on the module delivery from student respondents.

Over 80% of respondents to the survey either agreed or strongly agreed that the ethics module was well organized. 66% agree or strongly agree to recommend using this ethics module again. 77% agreed or strongly agreed that they felt confident in their knowledge of engineering ethics. These responses indicate that the overall student experience with the ethics module was positive. Breaking down the module into its components, 62% of the respondents agreed or strongly agreed that microlearning was a suitable way to teach ethics and 58% agreed or strongly agreed that they preferred this method to traditional lectures. A large number of students (79%) agreed or strongly agreed that the team case study was helpful to bridge the gap between microlearning series and applying the ASIDE model. This indicates that using online videos with associated formative quizzes followed by working in groups to evaluate ethics cases were very important to the overall success of the ethics module. For all 10 questions surveyed, the majority of responses either were neutral, or agreed/strongly agreed. The percentage of respondents that felt negatively about the experience was small, which is another indicator that in general the students were engaged and positive about learning engineering ethics through this ethics module.

Survey Question 2: Module Understanding

One purpose of creating a blended learning engineering ethics module was to provide a method to teach this important professional skill in a way that did not conflict with the other course content. If students chose to invest time to work on the microlearning videos and topic quizzes, they may be more willing to learn, and have better retention of material. The survey given to the students included Likert Scale questions that related to how much the students felt they learned using this ethics module. The responses to the Likert scale questions on module delivery are presented in Figure 2.

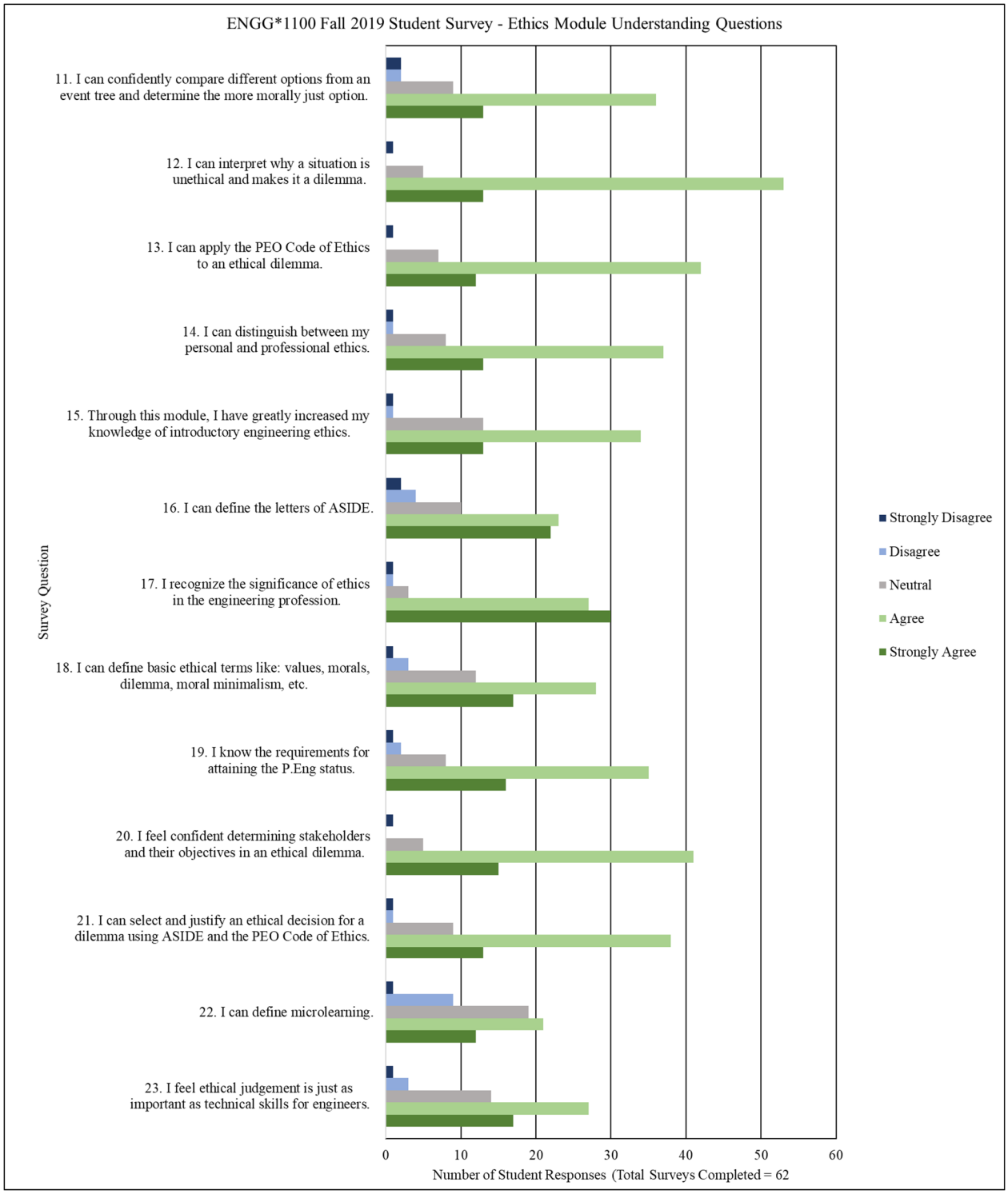


Figure 2: Likert scale opinions on module understanding from student respondents.

Based on the survey results, students felt very confident in the knowledge they gained through the engineering ethics module. For seven out of the thirteen questions, over 80% of the students agreed or strongly agreed with the statement. Another five questions had over 70% of the students agreeing or strongly agreeing. This large positive response indicates that the content of the individual components of the ethics module contained relevant information and was presented in a way that enhanced learning. Of note, 91% of the students agreed or strongly agreed that ethics is significant to the engineering profession, which may indicate that this method of delivery helped in increasing awareness of the importance of professional skills. The authors recognize that the case studies presented in this introductory module are relatively simple in the complex domain of engineering ethics. Notwithstanding, it is encouraging that the students have reported that they are confident in the knowledge gained through the engineering ethics module. The knowledge and methods can be applied to analyzing the more nuanced ethical dilemmas that they may encounter.

Engagement

To analyze student engagement with content, the results of the formative quizzes, practice quiz, team case study and final individual quiz were tracked. Figure 3 presents in chronological order through the semester, the number of students who participated in each individual component of the module, as well as the subset of students that completed all module components up to that point. The figure progresses from the six topic quizzes, to the practice quiz, to the team case study and then to the final quiz.

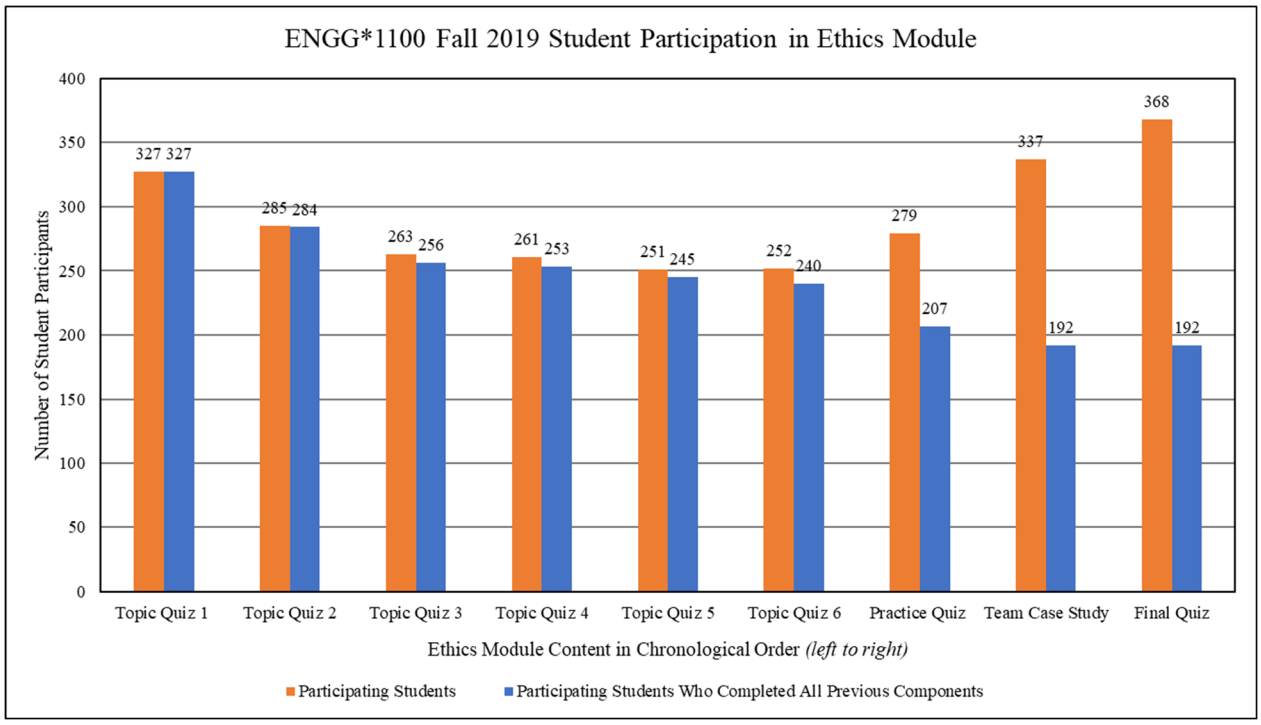


Figure 3: Student Participation in Components of Ethics Module.

To analyse student engagement during each component of the ethics module, the total student participation in a module component was compared to those students who had completed all the preceding components. We recognize there are instances where students completed a later quiz without completing the ones beforehand, and these cases have been removed. In the first week of

the ethics module, approximately 86% of the students enrolled in the course completed the first quiz. This was the highest participation level of any other formative component. The only two higher participation rates were for the graded team case study and final individual quiz, which were worth 1% and 4% of the student's final grade respectively. Over the six weeks of microlearning and topic quizzes, of the 327 students that completed week 1, 240 completed all six weeks for a retention of 73% for the microlearning component. High retention suggests the students were receptive, and willing to complete the microlearning component with the rest of the course work. Factors which would contribute to the loss of student engagement include the presence of midterms, extracurricular activities, and other competing academic requirements. Interestingly, there was a further 10% drop in student retention for the formative practice quiz, while the overall student participation number increased. This suggests that some of the 240 students that completed all weekly quizzes felt prepared enough for the final individual quiz to skip taking the practice quiz.

Ultimately, 192 students, or 50% of students enrolled in the course, completed the entire engineering ethics module. The two highest attendance numbers for an individual component of the ethics module were for the team case study and final individual quiz. The likely reasons for the higher participation numbers for these two activities are these two components were in-class portions, at a time regularly scheduled in the students' timetables, and both had graded outcomes with 1% of the student's mark available for the team case study, and 4% available for the final individual quiz.

For each of the non-graded components of the ethics module, total student participation was at least 65%, suggesting that students were open to, and saw value in completing the task. This willingness to participate in studious activities encourages engagement with information, thereby increasing class performance.

Impact of Online Modules on Performance – Ethics Quizzes

The effectiveness of the microlearning component was measured using the average grade of the MC quiz, as this portion of the final individual quiz was built from the prior six topic quizzes plus the practice quiz. The MC quiz consisted of questions taken directly from the topic quizzes as well as the practice quiz. The average grade for the MC portion of the final individual quiz is shown in Table 6.

Table 6: Average Grade Distribution Among Students Writing Final Individual Quiz.

Group Writing Final Individual Quiz	Number of Students	Average Grade for MC Portion
Students Completing All Topic Quizzes	237	74.85%
Students Completing Some Topic Quizzes	86	72.33%
Students Completing No Topic Quizzes	45	64.89%
Total Students Writing Final Individual Quiz	368	

Students who completed all six online components by watching microlearning videos and writing a formative topic quiz afterwards, had the highest average grade on the MC portion of the final individual quiz. Students completing none of the six had the lowest average grade.

Based on the survey results presented earlier in Figure 1, the in-class team case study portion of the ethics module was a useful tool to allow students to practice the knowledge gained through the online videos as they learned to evaluate ethical situations using the ASIDE framework. The ASIDE framework was mentioned in the microlearning videos and reinforced during the in-class

team case study. To evaluate the effectiveness of the blended learning environment, the averages of students that attended the team case study were broken into four categories: those that completed all the quizzes available (six topic quizzes plus the practice quiz), those that completed only the individual final quiz, those that only completed the practice and final quiz, and those that completed all of the topic quizzes and final quiz. The averages for these categories are presented in Figure 4.

Normality was assumed for groups with greater than 30 samples and tested for groups with less than 30 samples using *QQ-plots*. The *QQ-plots* exhibited strong linear behaviour indicating normality could be safely assumed. *Levene's test* was used to determine equal variances among the groups of students.

Figure 4 shows that students who completed all the topic quizzes performed about 10% better on average on the MC quiz questions than those who did not. An *ANOVA test* was done at the 5% level of significance and resulted in a p-value of 0.075, indicating there was not a significant difference in average grade performance on MC questions at the 5% level of significance. Although there is an observable difference in performance on the MC quiz questions between students completing and not completing the topic quizzes, the difference is not statistically significant at the 5% level.

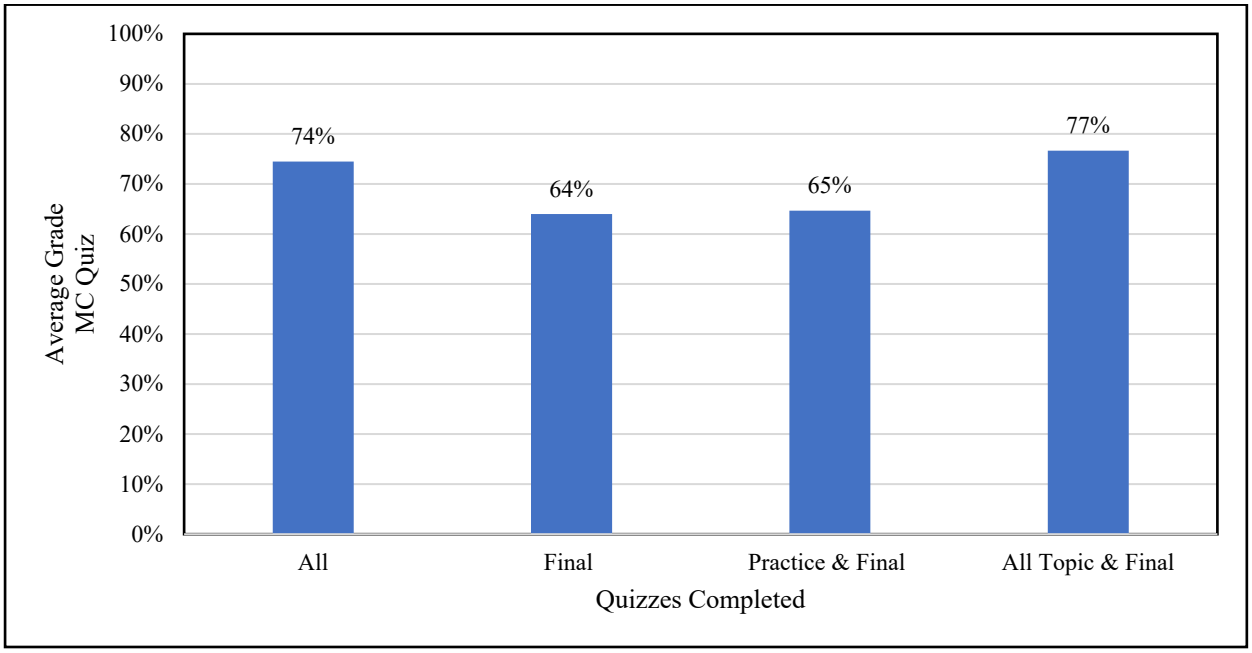


Figure 4: Average Grades for final individual MC quiz, categorized by quiz completion.

Impact of Online Modules on Performance – ASIDE Case Studies

A similar analysis was carried out, comparing the average grade differences in the ASIDE portion of the final individual quiz. The average grades are presented in Figure 5. A visual observation of the data shows an average difference of 7% between those that completed all the topic quizzes and those that did not. An *ANOVA test* on the average ASIDE grades resulted in a p-value of 0.029. This indicates there was a statistically significant difference between average ASIDE grades at the 5% level.

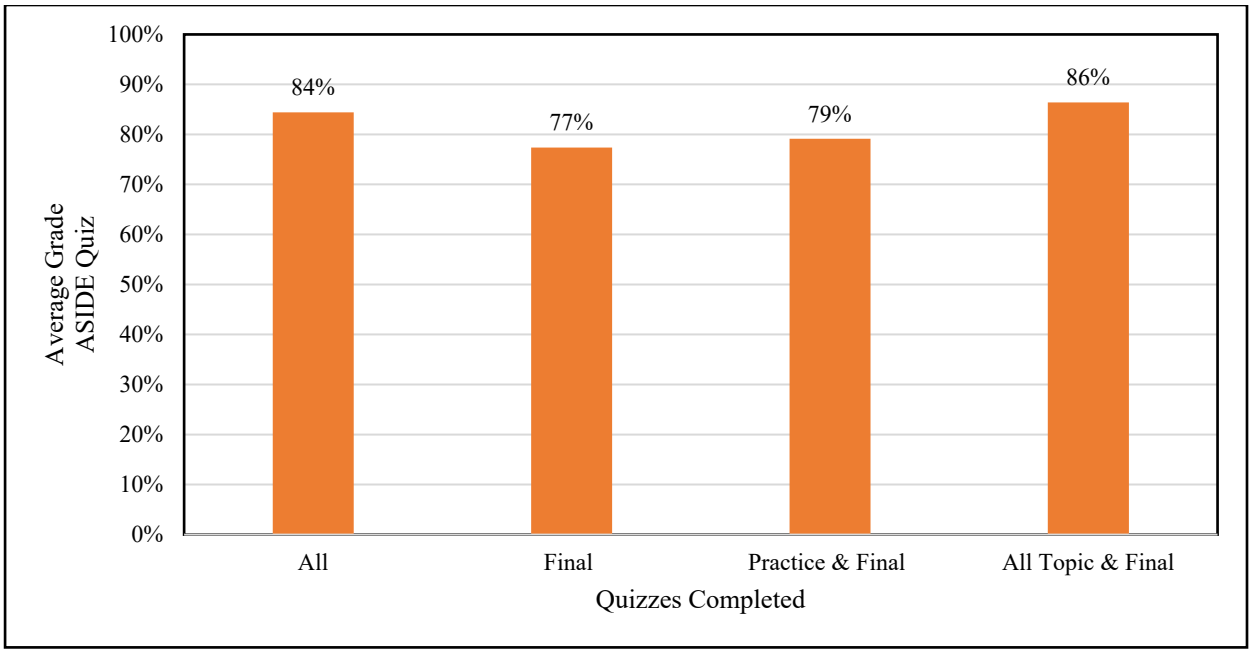


Figure 5: Average grades for ASIDE quiz categorized by quiz completion.

The average ASIDE grades show a significant statistical difference between the average grades of the four groups considered. A *Fisher's Least Significant Difference test* (LSD) with 95% confidence was done to determine the difference in performance between groups of students and presented in Table .

Table 7: LSD confidence intervals comparing (Group 1 – Group 2) ASIDE grades of two groups.

Group 1	Group 2	Lower Bound	Upper Bound
All	Final	0.39%	12.18%
All	Practice & Final	0.28%	14.31%
All	All Topic & Final	-3.58%	7.82%
All Topic & Final	Final	0.70%	16.10%
All Topic & Final	Practice & Final	0.83%	18.00%
Final	Practice & Final	-7.70%	9.73%

There was not a significant statistical difference found between *All* and *All Topic & Final*, as well as *Final* and *Practice & Final*. Looking at the confidence interval comparing "All Topic & Final" and "Practice & Final", we see the Topic quizzes produced final grades between 0.83 – 18% higher than those that completed the Practice quiz. From this, we infer the Topic quizzes were more effective than the Practice quiz for student learning when completing the ASIDE portion of the final quiz. Since this analysis only included students that attended the team case study, it is assumed that the only difference between students' grades was their degree of participation in the formative quizzes (i.e., topic quizzes/practice quiz). This may be a broad assumption as there are many other components that can affect student performance beyond the degree of their participation.

Blended Application of Microlearning and Case Study

The blended approach to microlearning was specifically implemented to bridge the learning of remembering basic ethical terms, to applying the ASIDE model. It was adopted in the form of a team case study done in-class in groups, to practice applying the ASIDE model taught through the online portion of the module. With a foundation in place for the knowledge required to build an ethical framework, the students were able to practice what they have learned with their peers to develop critical thinking and provide deeper meaning to the content they had learned online. This section will investigate if participation in the team case study had a statistically significant impact on the final individual quiz performance and whether the students did better or worse had they attended. Average student grades are presented in Figure 6. Looking at Figure 6, there appears to be a significant distinction in grade averages for final ASIDE grades, while the final MC grades appear to have little difference.

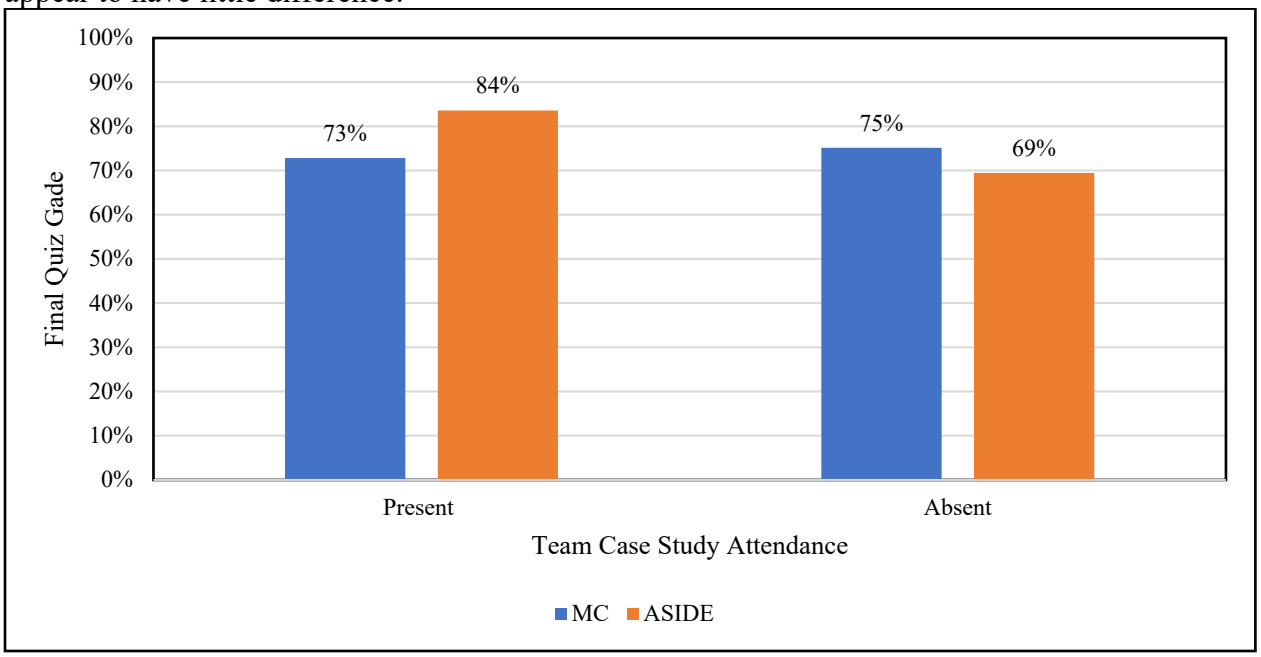


Figure 6: Average Grade Distribution of Students Absent and Present for the Team Case Study, disregarding the extent of participation in the online module.

Of the 368 individual quizzes that were written, 35 students did not attend the team case study. Using the central limit theorem, all sample sizes are sufficiently large to assume normality. An *F-test* was determined to have a significant statistical difference in population variances at the 5% level of significance. Thus, a *two-sample Welch t-test* was used to determine if there was a significant statistical difference between the average grades of the two-part individual quiz between the students that attended the team case study and those that did not. The test was done at the 5% level of significance.

When comparing mean scores on the MC portion of the final individual quiz, a p-value of 0.43 was calculated. The p-value for the ASIDE portion of the final individual quiz was 0.00008. These results indicate there was a significant difference in average student performance with regards to the ASIDE portion of the quiz when considering attendance to the team case study.

A Welch confidence interval with 95% confidence was created to compare the average ASIDE grades of students that attended the team case study, to those that were absent and presented in Table . Based on the difference in means of students present versus students absent, those that attended the team case study were expected to perform 8-21% better on the ASIDE portion of the quiz than students that were absent. This affirms the benefit of the blended approach when using a mainly online module to teach applicative learning. It also confirms the necessity of having a variety of learning structures in place when adopting microlearning as a component of a teaching plan. The in-person, practice session effectively bridges the students' learning from the simple repetitive online quizzes, to an individual critical thinking analysis. A sample of students 35 missing the practice quiz is relatively small compared with the number that attended to practice quiz. Collection of data in subsequent years may allow for further confirmation of these observations and results.

Table 8: Confidence interval for final ASIDE grade comparison (present – absent) for students that were present or absent from the team case study.

Lower Bound	Upper Bound
8%	21%

CONCLUSION

This study examined the effectiveness of microlearning modules in enhancing student engagement in, and understanding of, the application of engineering ethics in a first-year engineering design course followed by an applicative peer-to-peer learning session. Based on survey results, students were extremely receptive to the ethics module, including the quality of the delivery, their confidence in their knowledge of the content, and their willingness to participate in learning. The positive feedback toward activities is a positive indicator that suggests students enjoyed their learning and therefore inherently retained the content better than they might have without the microlearning components included. The survey data suggests that students were engaged with the microlearning content and indicates that the microlearning module was modestly more engaging than the traditional lecture-style.

Despite completing the online portion of the module in parallel with the rest of the course content, 73% of the students completed all the formative online quizzes, further suggesting they found the microlearning portion valuable to their learning and therefore engaging. Students who completed all topic quizzes, outperformed those that did not by 0-18% on the ASIDE portion of the final individual quiz, indicating there is a correlation between engagement with microlearning modules and student performance on quizzes.

The blended approach using microlearning techniques, a single in-class lecture and team case study was found to have benefits when it came to student performance. A Welch confidence interval of average final ASIDE grades of students showed those who attended are expected to receive a grade of 8-21% higher, than those that did not. Based on the positive survey response, and grade performance averages, the team case study was an essential component to teach students how to apply the ASIDE framework. The microlearning techniques employed in the ethics module were well received by the students and was reflected in the enhanced final ASIDE performance of those that completed all topic quizzes, compared to those that did not. Therefore, the use of a blended approach via in team case study and microlearning component has shown promise; though recognizing that the application is specific to this cohort and content provided is imperative.

This study has provided a look at how using microlearning in a blended teaching approach can be utilized to increase student engagement and performance in learning ethics content in a first-year engineering design course without demanding excessive investment of time by the student. Given this result, exploring the use of microlearning applications to extend the integration of engineering ethics and other professional skills in primarily technical courses is something to consider for future studies.

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This study has been reviewed and received ethics clearance through the University of Guelph Research Ethics Board (REB: 20-05-032).

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