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Blended Learning in an Upper Year Engineering Course: The Relationship between Students' Program Year, Interactions with Online Material, and Academic Performance

Ellen Watson
University of Alberta, ellen.watson@ualberta.ca
Luis F. Marin
University of Alberta, luisfern@ualberta.ca
Lisa N. White
University of Alberta, lisa.white@ualberta.ca
Renato Macciotta
University of Alberta, macciott@ualberta.ca
Lianne M. Lefsrud
University of Alberta, lefsrud@ualberta.ca

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Blended Learning in an Upper Year Engineering Course: The Relationship between Students' Program Year, Interactions with Online Material, and Academic Performance

Abstract

At a comprehensive, public university in Western Canada, a fourth-year course in risk and safety management was recently made a requirement for all engineering students; depending on their program, students may take this course in their second, third, fourth, or fifth year of their program. As a result of increasing class sizes, this course was shifted from traditional to blended instruction. Since blending and opening this course to students with varying years of undergraduate engineering experience, instructors noted a difference in students' maturity (e.g., a change in quantity and quality of in-class discussion, questions, participation, student-teacher interactions, and problem solving capabilities) and questioned whether this impacted their interactions with online material. Research examining the impact of blended learning in Engineering has primarily focused on large first-year undergraduate courses; research about blended learning in upper-year engineering courses is sparse. Studies investigating courses with students of varying years of experience in the program are virtually non-existent. Therefore, to better understand students' interactions with online material during blended learning as connected to years in their program, we examined the relationship between levels of interaction and performance of students by year in program. This study analyzed approximately 2000 students' interactions with online material and performance across five sections of a risk-management course in engineering. We found that students who had completed more years of their program interacted less with online material than students earlier in their undergraduate careers. Academic performance, on the other hand, was higher for students who had interacted more with online material and slightly higher for students who had completed more years in their program. These results suggest that the delivery of instructional materials may need to be tailored to students' year in their program. Further implications and areas of future study are discussed.

Dans une université polyvalente publique de l'Ouest du Canada, un cours de quatrième année sur la gestion des risques et de la sécurité a été récemment déclaré obligatoire pour les étudiants et les étudiantes en génie. En fonction de leur programme, les étudiants et les étudiantes suivent ce cours dans la deuxième, la troisième, la quatrième ou la cinquième année de leur programme. Suite au nombre grandissant d'étudiants et d'étudiantes dans les classes, ce cours est passé d'un cours traditionnel à un cours en apprentissage hybride. Depuis que ce cours est offert en apprentissage hybride à des étudiants et à des étudiantes qui se trouvent dans diverses années de leur programme et dont l'expérience en génie du premier cycle varie, les professeurs et les professeures ont noté une différence dans la maturité des étudiants et des étudiantes (par ex. changement dans la quantité et la qualité des discussions en classe, questions, participation, interactions entre étudiants et professeurs et capacités de résolution de problèmes) et se demandent si cela a eu des effets sur leurs interactions avec le matériel en ligne. La recherche portant sur les effets de l'apprentissage hybride en génie s'est principalement penchée sur les grandes classes de première année du premier cycle universitaire. La recherche portant sur les cours de génie des années supérieures est peu abondante. Les études de recherche sur les cours où sont inscrits des étudiants et des étudiantes qui se trouvent dans diverses années de leur programme sont pratiquement inexistantes. C'est pourquoi, afin de mieux comprendre les interactions des étudiants et des étudiantes avec le matériel en ligne dans un cours hybride tel que connectées à l'année de leur programme, nous avons examiné la relation entre les niveaux d'interaction et la performance des étudiants et des étudiantes par année du programme. Cette étude a permis d'analyser environ 2000 interactions d'étudiants et d'étudiantes avec le matériel en ligne ainsi que leurs résultats académiques dans cinq sections d'un cours sur la gestion des risques en génie. Nous avons constaté que les étudiants et les étudiantes qui avaient complété davantage d'années dans leur programme interagissaient moins avec le matériel en ligne que les étudiants et les étudiantes qui se trouvaient au premier cycle de leur carrière. Les résultats académiques, par contre, était supérieurs parmi les étudiants et les étudiantes qui avaient interagi davantage avec le matériel en ligne et un peu plus élevés parmi les étudiants et les étudiantes qui avaient complété davantage d'années dans leur programme. Les résultats suggèrent que la fourniture de matériel didactique devrait peut-être être adaptée à l'année dans laquelle les étudiants et les étudiantes se trouvent dans leur programme. D'autres implications et des domaines d'études futures sont discutés.

Keywords
blended learning; engineering, risk management, multi-year course; apprentissage hybride, génie, gestion des risques, cours offerts à des étudiants et des étudiantes de diverses années d'un programme

Currently, there is an increasing trend towards the use of blended learning in post-secondary education contexts (Clark et al., 2018; Karabulut-Ilgu et al., 2018; Krasnova & Vanushin, 2017). Blended learning is generally defined as a learning environment in which part of the learning is completed outside of class time, typically in an online environment, and part of the learning occurs during face-to-face instructional contact (Garrison & Vaughn, 2008). Research has found blended learning in undergraduate engineering courses led to improved student satisfaction and resulted in greater student engagement and class attendance, among other non-tangible benefits (Clark et al., 2016; Harris & Park, 2016; Jamieson & Shaw, 2016; Rahman, 2017; Ravishankar & Jones, 2017; Shanmuganathan, 2018). Results also indicate that engineering students perform better (improved final exam marks) in a blended learning environment, as compared to a traditional lecture format (Clark et al., 2016; Francis & Shannon, 2013; Karabulut-Ilgu et al., 2018; Rahman, 2017; Shannon et al., 2013; Singh et al., 2019). However, a number of questions remain regarding the purpose, timing, and appropriateness of using blended learning techniques in upper year engineering courses.

At a comprehensive, public university in Western Canada, a fourth-year course in risk and safety management has recently become required for all undergraduate engineering students. Prior to 2017, this course had only been required for fourth- or fifth-year students in one engineering program in this faculty and an upper year option for two other programs. Depending on their program, students may now take this course in their second, third, fourth, or fifth year of their degree. Since opening this course to second- and third-year students, instructors of this course have noted a significant difference in students' maturity (quantity and quality of in-class discussion, questions, participation, student-teacher interactions, and problem solving) and questioned whether this had impacted students' course interactions with online material and their subsequent academic performance.

To better understand students' interactions with online blended learning, we examined the interaction and performance of students by year in program. This four-year study analyzes approximately 2,000 students' interactions with online material and performance across 17 sections of a risk-management course in engineering. This course was delivered using a blended learning approach composed of two main components. The first was a traditional face-to-face lecture format accompanied by hands-on, in-class activities and "hands up" questions and answers. The second component consisted of a variety of online learning elements, such as quizzes, videos, instantaneous feedback surveys, and live surveys where students had an opportunity to submit questions online during the lecture for the instructor to address before the end of the lecture or at the start of the following lecture. In any blended learning course, students' interactions with online material on their own time is important to the success of the course (Garrison & Vaughan, 2008). Our instructional team worried about seeing a decrease in interactions with online material with lowering the program years of students. Hence, in this blended, multi-year engineering course, we asked: What are the interrelationships between students' (a) program year and their level of interaction with online material, (b) interactions with online material and their academic performance level, and (c) program year and their level of academic performance?

Literature Review

Different Types of Blended Learning

Liyanapathirana and Mirza (2018) outlined five blended learning models: supplemental, replacement, emporium, fully online, and buffet. Based on Liyanapathirana and Mirza's definitions, this risk-management course was offered using both a supplemental model for lectures and a replacement model for the tutorial time. In the supplemental model, the traditional lecture format is supplemented by additional out-of-class activities to improve student learning. Contact hours for the lecture could not be reduced (due to accreditation requirements), ergo a supplemental model was ideal where the online material was meant to supplement what was being discussed in class. The tutorial, on the other hand, centered on students' working on a group project. To increase students' autonomous working time, a replacement model was used so that less time was spent in lectures with the balance of available time being replaced with online activities and group working time.

Online material required for lectures typically consisted of pre-reading or viewing of videos to contextualize upcoming content, introduce the simpler aspects of a topic, or review content students should have learned prior to the course. Tutorial time was dedicated to the completion of a large risk analysis project where students produced a report for an engineering related incident. Tutorials were redesigned in 2017 to have students view (and interact with) online material prior to coming to class so that the in-class time could be dedicated to active-learning focused on various aspects of their risk analyses.

Does Blended Learning Improve Engineering Student Success?

Overall, undergraduate engineering students report that they have benefited from using blended learning techniques. Jamieson and Shaw (2016) found blended learning in fourth-year undergraduate engineering design courses resulted in greater student satisfaction and motivation, as well as improved class attendance and collaboration among students. Similarly, Rahman (2017) found that a blended learning format in fluid mechanics engineering courses improved student satisfaction by 18%. Ravishankar and Jones (2017) found the use of blended online materials in advanced engineering courses improved both student engagement and attendance in face-to-face lectures. Meyers (2016) found learning, interest, and engagement improvements based on feedback from a first-year engineering cohort. Harris and Park (2016) also reported positive student feedback, such as the flexibility to watch the videos on their own time, learn the material at their own pace, and participate more during lectures. Similarly, Clark and colleagues (2016) also reported benefits, including increased student-teacher interaction, student teaming, individualized support, self-paced learning, increased problem solving and concept application, and flexibility in accessing online materials. Further, these authors found students in blended learning environments exhibited significant improvements in relation to problem solving, time to mastery, conceptual understanding, and student discussion and questions. Finally, Shanmuganathan (2018) also reported improvements in problem-solving skills, conceptual understanding, student retention and satisfaction in undergraduate engineering courses.

In general, it appears that students' academic performance levels improve with the adoption of blended learning. Using four yearlong case studies, Francis and Shannon (2013) found engineering and architecture students who do not engage with blended learning tended to show lower levels of achievement than their more engaged colleagues. Shannon and colleagues (2013) found a general correlation between the number of times students accessed online blended learning materials and their resulting grades. Even taking time to reflect on what they have learned increased students' marks by up to one half standard deviation (Chen et al., 2017; Di Stefano et al., 2016). In their review of recent meta-analyses, Clark and colleagues (2016) reported that when students watched video lectures beforehand to obtain the foundational knowledge and then demonstrated these skills during class in engineering courses, exam marks increased by half a standard deviation (on average) and resulted in a 12% reduction in the average failure rate. Further, student discussion, questions, and problem solving were significantly improved with these strategies. Similarly, Rahman (2017) reported that introducing online recorded lectures and tutorials, handwritten tutorial solutions, discussion boards and online practice quizzes into undergraduate fluid mechanics courses resulted in higher average marks and an increase in completion rates. Singh and colleagues (2019) reported significant improvement in exam performance with the adoption of blended learning techniques in a second-year electrical engineering course (pass rate increased from 60% to 86% and the average mark increased from approximately 50% to 63%). Finally, Karabulut-Ilgu et al. (2018) reported that engineering students in a blended learning environment performed as well as, if not better than, students in a traditional lecture format, based on an assessment of mean final course grade, as well as exam and quiz results.

It should be noted that not all relevant research reported improvements in student marks with the adoption of blended learning techniques. Jamieson and Shaw (2016) did not find a correlation between the number of times online materials (videos, assignments, and team project resources) were accessed and the final mark in their fourth-year engineering design course. Further, Clark and colleagues (2016, 2018), and Harris and Park (2016) found exam results were mixed from a statistical improvement standpoint in undergraduate engineering courses utilizing a blended learning format. Setren and colleagues (2018) found that differential effects might be due to the nature of the material being taught. They found that blended learning (watching video lectures prior, with exercises in class) benefits math students by as much as 0.3 standard deviations, but not economics students, whose courses have more lecture and theoretical problems. This suggests that type of course influences the success of blended learning when used with undergraduate students.

The variation in students' success with blended learning may also be due to different blended learning techniques being used for different purposes by different instructors. Torrisi-Steele and Drew (2013) found variation in how blended learning was being used in higher education; some academics use it for course management and efficiency, while others fully integrate blended learning techniques into the curriculum for enriched, innovative learning experiences. The degree to which blended learning is fully implemented depends upon: instructors' perceptions of usefulness; the availability of professional and technical support; resources such as funding for development, preparation time, institutional infrastructure, and involvement of senior staff; and efficacy (Torrisi-Steele & Drew, 2013). Harris and Park (2016) further noted that student performance depends more on the comprehensive implementation of a pedagogy (in their case flipped classrooms versus blended learning), rather than the choice of a specific pedagogy.

Additionally, it may be that prior student performance is a better indicator of how well students interact with blended learning material and, subsequently, how they will perform in the course. Contradicting Jamieson and Shaw (2016), Green and colleagues (2018) found student learning outcomes could be predicted by the results of students' previous academic study but the level of interactions with online resources in a second-year anatomy course had a significant additional impact on these outcomes. The authors compared three programs and found that students with a prerequisite grade obtained higher grades and were more likely to engage with online course materials. Students with higher marks going into the course were more likely to interact more intensely with the online content (videos and discussion forums), resulting in better marks in comparison to students with lower marks going into the course, who did not interact as actively with the blended learning content.

Looking beyond course grades, Liyanapathirana and Mirza (2018) reported a significant decline in attendance in lectures (from 80% pre-implementation to about 25% post-implementation) after the introduction of supplemental blended learning format in Australian engineering courses. In this case, lectures were recorded and posted online a few hours after the completion of the lecture, although only a small percentage of students watched lectures online throughout the semester, with numbers only increasing in the last few weeks before the final exam. Concerns regarding this trend were raised in terms of the students' ability to achieve course learning outcomes and improving team-building skills and collaborative problem-solving abilities. If students who interact more often with online material tend to have higher grades (per Green et al., 2018) and blended learning can lead to a decline in lecture engagement, then it is especially important to find an optimally effective format in which students interact asynchronously with online material and also actively participate during synchronous classroom interactions. Given the importance of team-building and collaboration across students (within and across seniority), does this online interaction vary with the years of experience a student has in an undergraduate engineering program?

Is Blended Learning Effective for Students in Higher Program Year Undergraduate Courses?

There appears to be a paucity of research investigating how engineering students in higher program years perform in blended learning environments. The few studies in this area have reported positive results. Taylor (2018) found the blended learning cohort of a fourth-year engineering design course showed the lowest proportion of students achieving below 50% on the final exam (as compared to the previous four years of course delivery in a traditional format). However, the author also reported that the students' mean final marks in the course aligned with their pre-entrance grade point average, regardless of the course delivery format (Taylor, 2018). Ravishankar et al. (2018) also reported a better class average and improved student satisfaction resulting from the use of a blended learning format in a fourth-year electrical engineering course over a three year period, as well as a decreased number of students in the "borderline" mark category (scoring 46% to 54% as a final grade). Finally, Clark and colleagues (2016) reported that students in several fourth-year blended learning STEM courses performed statistically equivalent or better than those in a non-blended learning environment, "with an overwhelming majority performing at a high level on the final exam, as never seen before" (p. 6). Blended learning appears well suited to students in upper program year engineering courses.

On the other hand, students' familiarity with a blended learning format and general beliefs about the effectiveness of online learning may have more to do with their success in the course overall. Clark and colleagues (2016) noted that when blended learning was introduced for the first time in a fourth-year course, students showed resistance to, and dissatisfaction with, the format and commented that the format should have been implemented before their final year of studies.

Joosten and Cusatis (2020) found that students' preference for social interactions, online work skills, and beliefs that online learning, an important aspect of blended learning, can be as effective as traditional classroom learning significantly predicted students' grades, perception of learning, and satisfaction. Correspondingly, fourth-year students rated their satisfaction with their first blended learning course at 2.75 out of 5, as compared to second- and third-year students, who rated their course at 3.49 out of 5. Harris and Park (2016) similarly found that some third-year engineering students struggled to adapt to a (first-time) blended learning environment and became frustrated during the initial adaptation period of the course. However, by the end of the course, the authors reported that students believed that they had learned the course material better and were better prepared for exams in a blended learning environment.

Given that blended learning can improve student achievement in engineering courses (Ravishankar & Jones, 2017) and that increased interaction with online materials can also improve student scores in STEM (Green et al., 2018), it seems obvious that instructors would want students to be as engaged as possible with online material. Further, students who have had more opportunities to experience this environment tend to better adapt to blended learning and more senior students are more likely to have experienced blended learning. However, there are no studies investigating the impact of students' experience in program on interaction with online material in a blended course. Hence, our team set out to investigate whether students' years in their program could have an impact on their interaction with online materials and, consequently, potentially their academic performance in the course.

Method

Course Context

Beginning in the fall of 2016, we focused on transforming a fourth-year risk management course to a blended format. In this context, the term "blended format" meant the course used both online and face-to-face content delivery (McGee & Reis, 2012), specifically in both a supplemental and replacement model as defined by Liyanapathirana and Mirza (2018). Tutorial work is primarily blended; students are expected to interact with online content (case study and text materials, videos, and quizzes) prior to coming to the tutorial where they engage in activities applying the learned content (including instantaneous feedback surveys—multiple choice, short answer, true/false and live surveys). The group project in this course is the focus of their weekly tutorial and worth one third of their course grade. In this group project, students assess a major incident (explosion, fire, building collapse, plane crash, etc.) and produce a risk management report for the consideration of their "employer." Each week, students learn the skills to produce a new piece of the report with several weeks aimed at peer-evaluation and instructor feedback on the progression of the report.

Since the winter of 2017, enrollment in this course has grown from an average of 100 students per academic year (consisting of primarily fourth-year students) to approximately 600 students per academic year (typically ranging from second- to fifth-year students). This growth is primarily due to this course becoming a required component of all engineering disciplines, whereas it was previously a requirement of only one discipline and an option in two others. As a fourth-year (400-level) course, the course had been designed to engage the fourth- (or fifth-) year engineering student. However, given students' overfilled course programming, engineering disciplines have inserted this risk management course as early as second year.

Data Collection

This study used online interaction data collected from the learning management system (LMS) used to facilitate content sharing in this course. Data was collected from five course offerings between the fall term of 2017 and the winter term 2019. These offerings were included in this study because of their consistency in the online activities required of students. This yielded 865 student data points. See Table 1, below, for a breakdown of the number of students per course. The University's Research Ethics Board approved the collection of this data, process number Pro00048272.

In this study, LMS logs were used to extract students' program year, interactions with online blended learning materials, and academic performance. LMS data was extracted, collated, and anonymized by an educational advisor after each course had been completed and the grades had been finalized. Students' program year was calculated as the number of academic years since their year of entry, as shown in their LMS records. Log records were used to identify which objects were accessed by each student (e.g., "Quiz 1") and the nature of each interaction (e.g., "viewed" or "submitted"). These records of students' interactions were used to compute the total number of objects accessed and the total number of unique actions taken on these objects by each student, calculated by counting each student's unique actions on each unique course object. For example, a student which viewed (+1), started (+1), submitted (+1) and reviewed (+1) their "Quiz 1" would have had four unique actions counted. To measure performance, students' overall course grades were used.

Data Analysis

This section describes the sample and results of the analyses used to test our research questions: What are the interrelationships between students' (a) program year and their level of interaction with online material, (b) interactions with online material and their academic performance level, and (c) program year and their level of academic performance? Scatter dot and boxplot visual representations and correlation analyses were used to describe the data and answer these questions.

Descriptive Statistics

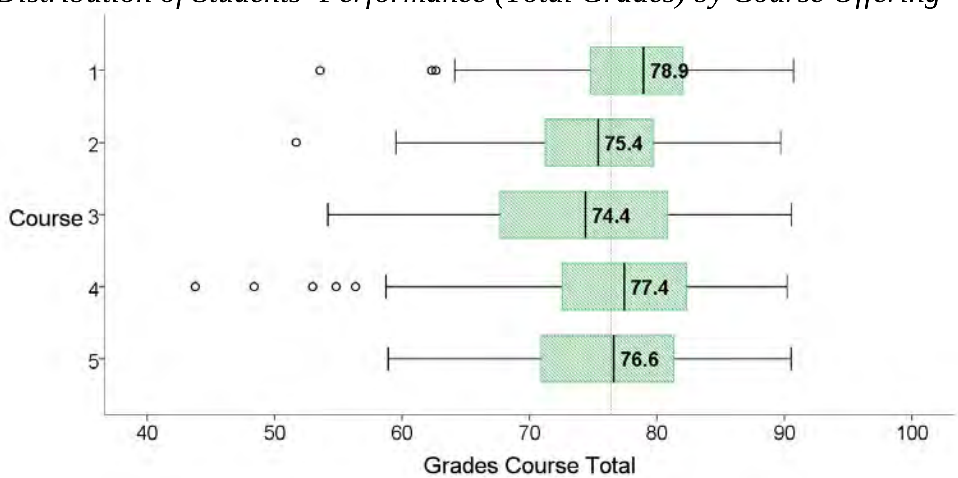
In total, 865 students participated in the five sections of the course between Fall 2017 and Winter 2019 (Table 1). The minimum number of students was 85 (Spring 2018) and the maximum was 318 (Fall 2018). Participating students were typically in their third or fourth year of their undergraduate engineering studies (M = 3.59, SD = 0.68), with varying distributions of program year between course cohorts. The average program year was 3.3 in the first course offering (SD = 0.7), 3.0 in the second (SD = 0.41), 3.1 in the third (SD = 0.46), and 3.9 in the fourth (SD = 0.6) and fifth (SD = 0.5).

Table 1
Number of Students by Course Offering and Program Year

Course Offering	Total Number of Students	Number of Students by Program Year						
		2	3	4	5	6	7	8
1. Fall 2017	163	10	89	59	4	1		
2. Winter 2018	133	9	117	5	2			
3. Spring 2018	85	2	78	3	1	1		
4. Fall 2018	318	4	50	243	15	3	2	1
5. Winter 2019	166		23	133	8	2		
Total	865	25	357	443	34	7	2	1

Over these five course offerings, the average final grade was 76.4% (*SD* = 7.2, Figure 1). Course offerings were somewhat consistent, with the maximum average in the first (*M* = 78%, *SD* = 6.1), the lowest in the second (*M* = 75.2%, *SD* = 6.5) and third (*M* = 74.1%, *SD* = 8.3), and the fourth (*M* = 76.8%, *SD* = 7.6) and fifth in between (*M* = 76%, *SD* = 7.0). Course total grades were normally distributed in course offerings two, three, and five according to Kolmogorov- Smirnov's (KS_2 = .07, KS_3 = .05, KS_5 = .06, $p > .05$) and Shapiro-Wilk's tests (SW_2 = .98, SW_3 = .98, SW_5 = .99, $p > .05$). Due to outlying lower grades, the first (KS_1 = .08, p = .013; SW_1 = .97, p = .002) and fourth course offerings (KS_4 = .06, p = .007; SW_4 = .96, p = .000), and the overall distribution of course total grades were not normally distributed (KS = .05, p = .000; SW = .98, p = .000).

Figure 1
Distribution of Students' Performance (Total Grades) by Course Offering

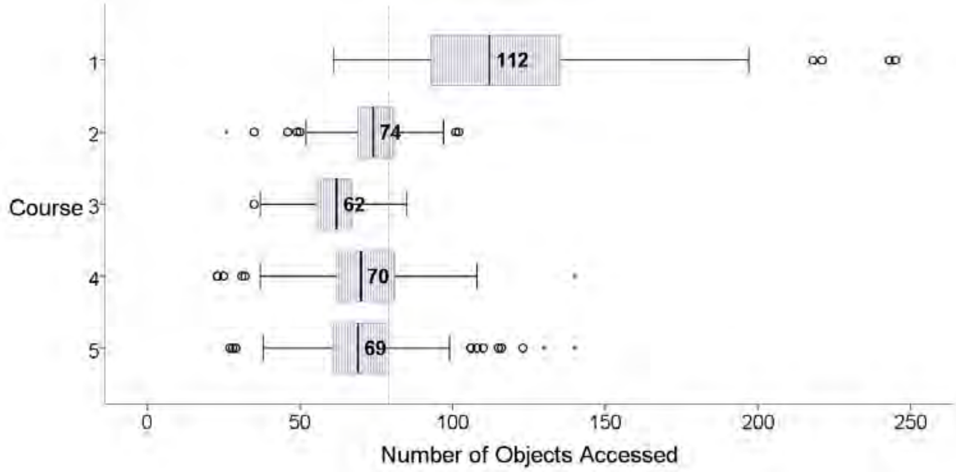


As mentioned previously, the LMS was used to manage coursework, maintain a public forum, share course material and provide tools for assessment. The number of objects accessed was computed by counting each student's first interaction with each unique object. On average, the number of objects accessed by students in these course offerings was 79.11 (*SD* = 26.75, Figure

2) with a minimum of 23 and a maximum of 245 objects accessed (range = 222). The number of objects accessed varied from term to term as the blended learning material and the schedule varied and evolved slightly (Figure 2). On average, students accessed 117 objects in the first course offering (*SD* = 33.3), 74 in the second (*SD* = 11.5), 61 in the third (*SD* = 8.9), and 71 in the fourth (*SD* = 14.9) and fifth course offering (*SD* = 17.1). The distribution of objects accessed was normally distributed only in course offering three (KS = .08, p > .05; SW = .97, p > .065) but not in the other offerings, due to a number of large outliers (KS = .15, p = .000; SW = .84, p = .000).

Figure 2

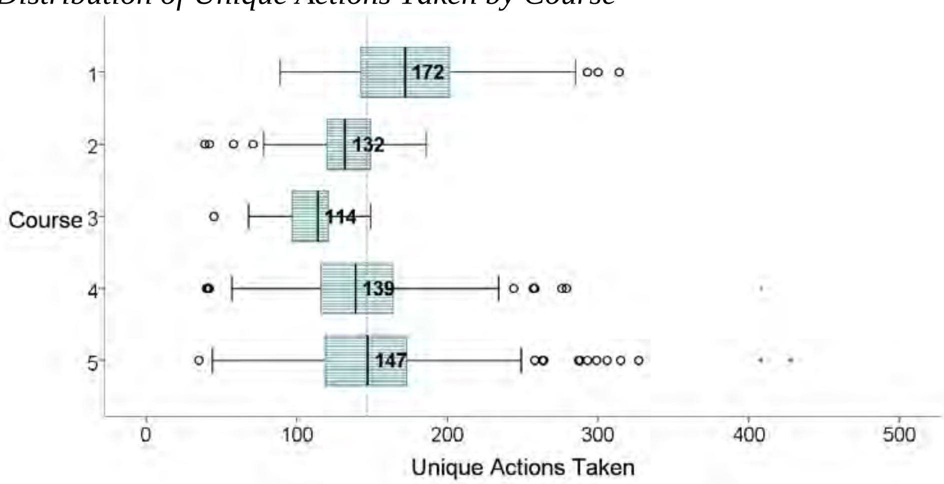
Distribution of Number of Course Objects Accessed by Course



Overall, the average number of unique actions taken by students was 146.3 (*SD* = 46.03, Figure 3), with a minimum of 35 and maximum of 428 (range = 393), and a non-normal distribution due to a number of large outliers (KS = .09, p = .000; SW = .93, p = .000). The number of unique actions taken also varied from term to term with the highest average number in course offering one (*M* = 172, *SD* = 41.3), the lowest in course offering three (*M* = 114, *SD* = 19), two (*M* = 132, *SD* = 25), and four (*M* = 139, *SD* = 42.5) and course offering five in between (*M* = 147, *SD* = 59.1). None of these distributions was found to be normally distributed.

Figure 3

Distribution of Unique Actions Taken by Course



Relationships

Spearman correlations measure the strength of monotonic relationships between interval, ratio level, or ordinal paired data with no requirement of normality. Two-tailed Spearman correlations (*N* = 865) were used to verify the relationship between the non-normally distributed students' performance, program year, course cohorts, and two interaction indicators: number of objects accessed, and unique actions taken (Table 2). There was a weak positive relation between students' performance and program year ($r = .12$, $p < .001$; Figure 4) and between students' performance and their interactions with blended materials: total number of objects accessed ($r = .26$, $p < .001$; Figure 5) and unique actions taken on the LMS ($r = .27$, $p < .001$). Students who obtained higher grades also interacted with a larger number of objects, performed a larger number of unique actions, and had completed slightly more years in their program.

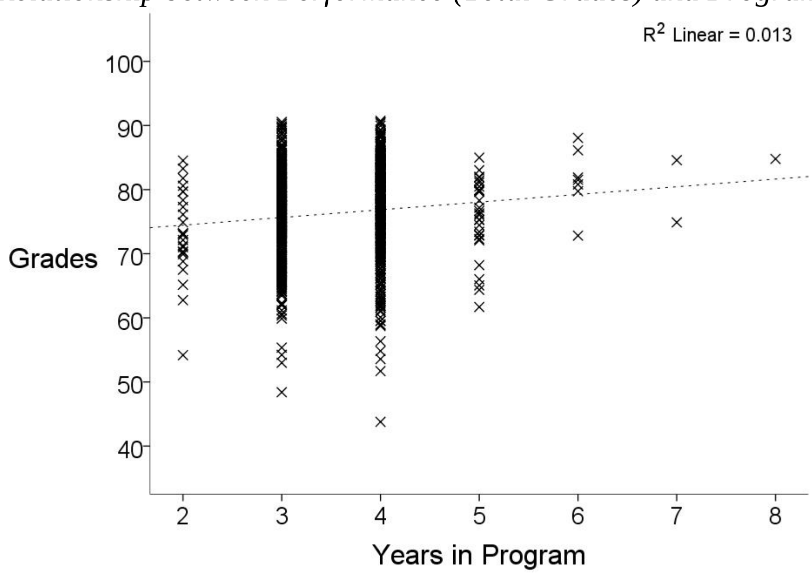
Table 2

Relationships Between Student Grades, Years in Program, and Interactions.

	Performance (Total Grade)		Program Year		Course Offering	
	r	*p*	*r*	*p*	*r*	*p*
Performance (Total Grade)			.12**	.000	-.03	.299
Program Year	.12**	.000			.50**	.000
Course Offering	-.03	.299	.50**	.000		
Objects Accessed	.26**	.000	-.12**	.000	-.42**	.000
Unique Actions Taken	.27**	.000	.04	.177	-.09**	.007

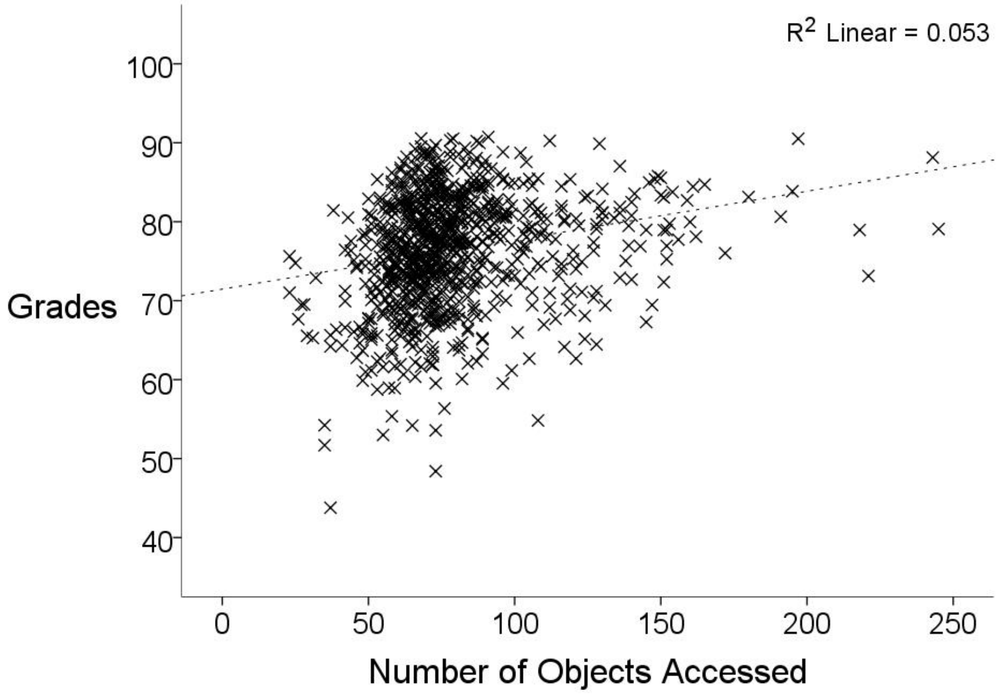
Figure 4

Relationship between Performance (Total Grades) and Program Year



There was also a very weak negative relationship between program year and students' interactions with blended learning materials: number of objects accessed on the LMS (r = -.12, p < .001; Table 2) but not the number of unique actions taken (r = .04, p = .177; Table 2). Students with more years in their program tended to interact with slightly fewer course objects. Finally, there was a moderate positive relation between course offering and students' program year (r = .5, p < 0.001; Table 2), a moderate negative relation between course offering and number of objects accessed (r = -.42, p < .001) and a very weak negative relation between course number and unique actions taken (r = -.09, p < .01).

Figure 5
Relationship between Performance (Total Grades) and Number of Objects Accessed



Relationships with Centered Values

Considering the variance observed between course offerings (students' performance, program year, and online interactions—objects accessed and unique actions taken), all variables were transformed into centered values using the mean for each course offering. Centering was used to facilitate the interpretation of results and improve comparability between course cohorts' values. Two-tailed Spearman correlations (N = 865) were used on these new centered values to verify the relationship between students' performance, program year, objects accessed, and unique actions taken (Table 3). With course-centered values, there is still a positive relationship between performance and program year (r = .10, p < .01; Figure 6) and between performance and interactions: total number of objects accessed on the LMS (r = .23, p < .001; Figure 7) and unique actions taken (r = .23, p < .001). Students' relatively higher performance interacted with relatively larger number of objects accessed, performed a relatively larger number of unique *actions* on the LMS and had a relatively higher program year.

Figure 6
Relationship Between Centered Performance (Total Grades) and Centered Years in Program

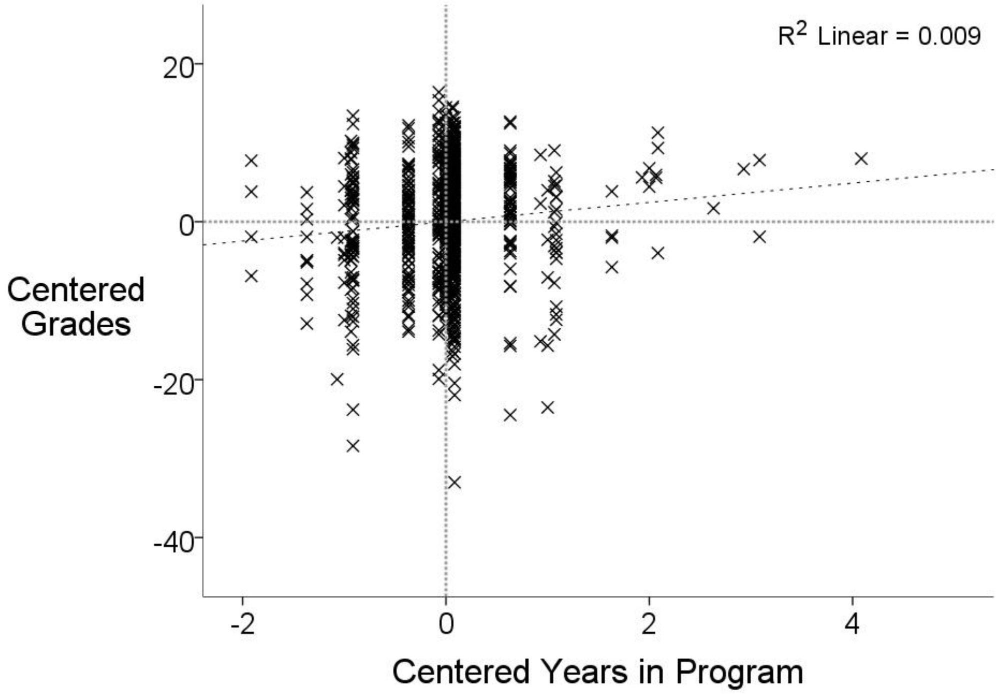


Figure 7
Relationship Between Centered Total Grades and Centered Number of Objects Accessed

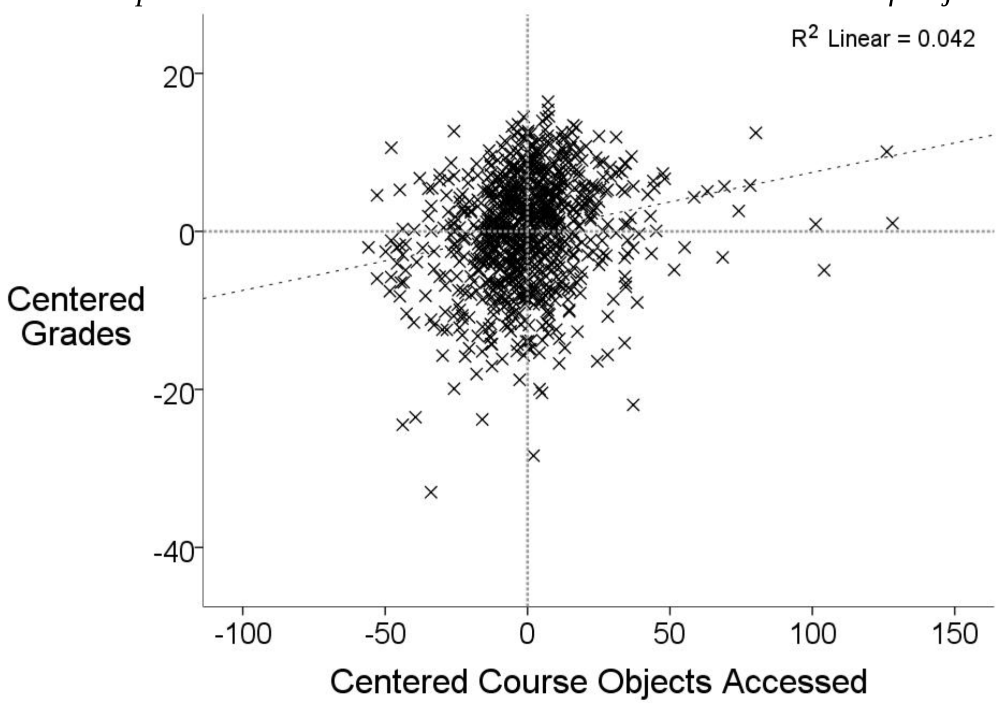


Table 3

Relationships between Students' Centered Performance, Program Years and Interactions with Blended Materials (Objects Accessed and Unique Actions)

	Students' Performance		Program Year		Course Offering	
Centered variables	*r*	*p*	*r*	*p*	*r*	*p*
Students' Performance			.10**	.003	.007	.831
Program Year	.10**	.003			.19**	.000
Course Offering	.007	.831	.19**	.000		
Objects Accessed	.23**	.000	-.07	.054	-.004	.899
Unique Actions Taken	.23**	.000	-.05	.106	-.06	.059

Relationships by Course Offering

To verify the prevalence of the relationships found, two-tailed Spearman correlations were used on centered values separated by course offering (Table 4). A weak positive relationship found between students' performance and program year was confirmed on the 1st course group (r = .26, *N* = 163, p < .001). Students in the first course offering who obtained higher grades also had a slightly higher program year than the rest of their classmates (Figure 8).

The relation between students centered unique actions taken and performance (total grades) was confirmed on two course offerings (*c1*, r = .17; *c4*, r = .35). Students in the first and fourth course who obtained higher grades also performed a slightly larger number of unique actions taken on the LMS (Figure 9). The relation between students' centered performance and course objects accessed was confirmed in 4 out of 5 course offerings (*c2*, r = .23; *c3*, r = .32; *c4*, r = .33; *c5*, r = .18). Except for students in the first course offering, students who interacted with a larger number of objects also obtained higher grades (Figure 10). While the monotonic relationship shown in the first course offering is almost horizontal (i.e., no relation), the relationships shown in courses offerings 2 to 5 are monotonically increasing: as students' number of objects accessed increase, their performance (total grades) never decrease. Overall, students who interacted more with the online course objects also obtained higher grades.

Figure 8

Relationship Between Students' Centered Performance and Program Year by Course Offering

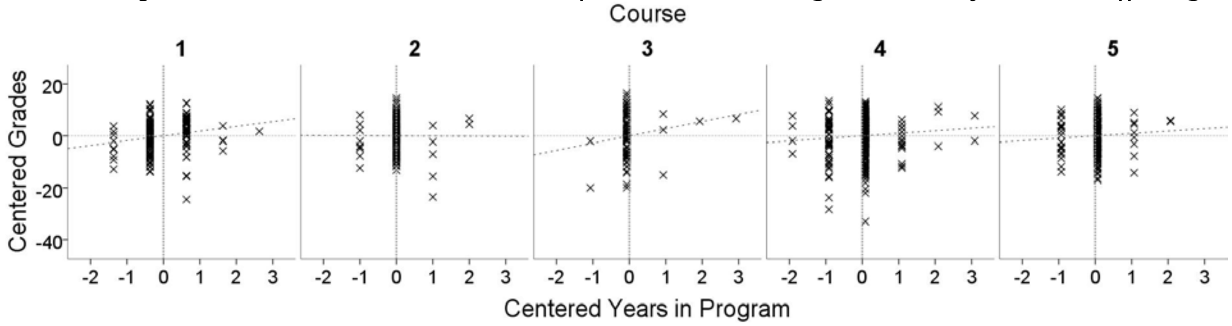


Table 4
Relationships between Centered Student Performance (Total Grade), Program Year, and Interactions by Course Offering

			Performance (Centered)		Program Year	
Course	*n*	Centered Variables	*r*	*p*	*r*	*p*
Course 1	163	Performance (Grade)			.26**	.001
		Program Year	.26**	.001		
		Objects Accessed	0.14	.074	-0.10	.189
		Unique Actions Taken	.17*	.035	-0.12	.137
Course 2	133	Performance (Grade)			0.03	.734
		Program Year	0.03	.734		
		Objects Accessed	.23**	.006	0.06	.491
		Unique Actions Taken	0.16	0.06	0.05	.559
Course 3	85	Performance (Grade)			0.15	.159
		Program Year	0.15	.159		
		Objects Accessed	.32**	.003	0.00	.983
		Unique Actions Taken	0.19	.089	0.01	.967
Course 4	318	Performance (Grade)			0.05	.371
		Program Year	0.05	.371		
		Objects Accessed	.33**	0	-0.07	.219
		Unique Actions Taken	.35**	0	-0.02	.712
Course 5	166	Performance (Grade)			0.05	.487
		Program Year	0.05	.487		
		Objects Accessed	.18*	.021	-0.05	.511
		Unique Actions Taken	0.15	.054	-0.06	.471

Figure 9

Relationship between Students Centered Performance and Unique Actions Taken by Course

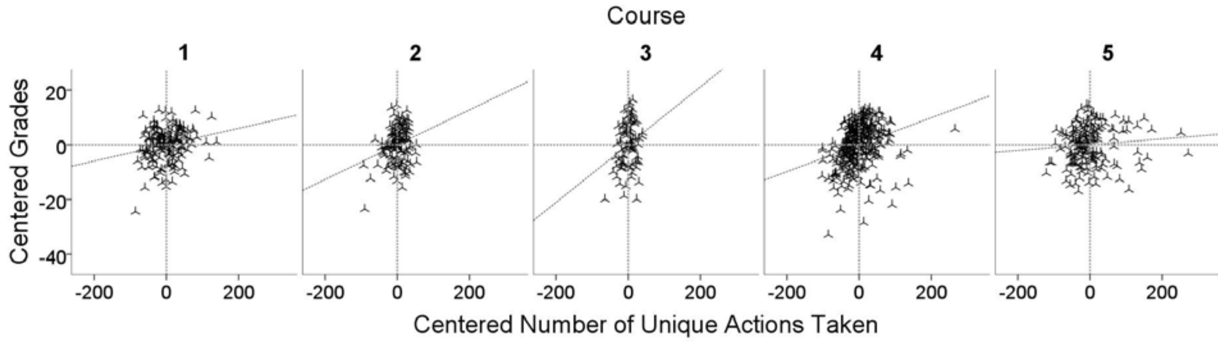
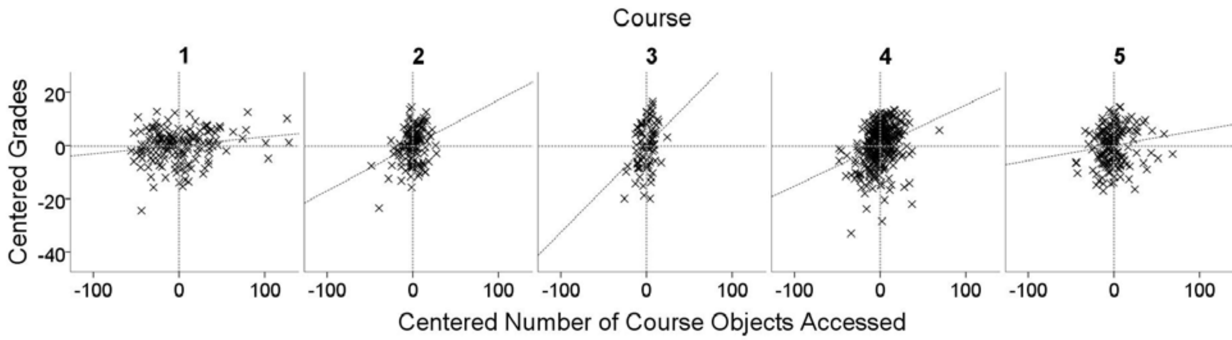


Figure 10

Relationship between Students Centered Performance and Course Objects Accessed by Course



Discussion

Our research was motivated by a dual challenge: How could we deliver a senior engineering course to a growing cohort, while also tailoring material to increasingly diverse disciplines and student maturities? Our solution was to develop a blended learning course in a replacement and supplemental format: some materials are delivered online prior to the tutorial (case study and text materials, videos), with face-to-face learning being supplemented with online quizzes, feedback surveys, and live in-class surveys.

We wanted to know whether students' year of progression in a program impacted their level of interactions with online material in a blended course. In response to our first question, we found that students who had completed a higher number of years in their program tended to access slightly fewer objects online. This finding was significant without centered values but not found significant with centered values. This indicates that the relationship without centered values may be better explained by other underlying differences between course cohorts. We also found no significant difference between students of differing years in their program and the number of unique interactions they took online.

Our second question sought to compare students' interactions with online materials with their success in the course; we found that students had higher grades when they interacted with a larger number of course objects and had more unique interactions. These findings held significant for centered values. It was clear that students' grades were connected to their online interaction in this blended, multi-year engineering course.

Finally, our third question asked whether students' success in this course could be associated with the number of years completed in their program. Our data shows that students in a higher program year tended to have higher grades in this course (absolute and centered values). This finding was significant for students in the first course offering but was weakly positive for each of the four other course offerings. As this is a risk management course, our research team wondered about the underlying factors that may be contributing to the association between course offering, years in program, and grades. At our university, students are able to take on a cooperative education program whereby they gain real-world experience through employment through multiple work placements during their program. It is very possible that a larger cohort of students in the first course offering in this study who had completed more years in their program may have also been employed in engineering settings that required risk management expertise. If this was the case, these students entered this risk management course with more advanced prior expertise, and this could explain the higher performance in that course. Unfortunately, we did not collect data regarding students' experience with risk management content prior to entering this course. This is a limitation to our study, and we would recommend that future research examine students' expertise to deepen our understanding of performance in multi-year, undergraduate engineering courses.

It should also be noted that we question whether students' final grades were the best measurement of performance in the blended, undergraduate engineering course. Beyond final grades, instructors noticed that other outcome variables—the quality of in-class discussion, questions, participation, student-teacher interactions, and problem solving—were significantly higher in the blended learning format (as found by Clark et al., 2016) than the previous traditional lecture format. Our future research will include other outcome measures such as students' interest in the course material, student teaming, individualized support, self-paced learning, and flexibility in accessing online materials. Further, we assume that the higher achievers will likely interact more frequently and have higher outcomes, which does not necessarily imply causality. To examine this, next we will control for students' prior grade point average.

As we found that students in higher program years could have generally higher grades and fewer interactions with online material, this suggests that we could adopt elements of a buffet model to better meet the differing needs of our students' disciplines and maturities. For example, we could create versions of the case studies that include differing materials (videos, slides, diagrams, failure calculations) with more and less technical detail, to determine if these are more/less appealing based upon students' program year. Further, the creation of case studies that illustrate key theoretical principles that are tailored to the differing disciplines (i.e., cybersecurity for electrical and computer engineering students, rotating equipment failure for mechanical engineers, dam failures for civil engineers) may also be more appealing to students. By measuring the variable interactions with online material, satisfaction with materials, and application of materials versus course performance, we could determine if such a buffet model benefits students' learning needs.

Conclusion

This research shows an association between absolute and centered students' program year, interactions with online material, and academic performance. In our blended learning upper year Engineering courses, students who obtained higher grades also interacted with a larger number of objects, performed a larger number of unique online actions, and had completed slightly more years in their program. These results may not be statistically generalizable because students were not randomly selected but already enrolled (by choice or necessity) in this course. Results were observed within a real-life context, after the learning situation had occurred, with natural variation amongst variables in a comprehensive, public university in Western Canada. However, while we have theoretical generalizability (supported by our comparison with previous research), these results may be analytically generalizable if replicated in more diverse contexts.

To deepen our understanding of the relationship between our multi-year, undergraduate engineering course interventions, students' interactions with online materials, and students' performance, future research should examine additional variables. This would include: students' expertise, prior grade point average, online work skills, beliefs about the effectiveness of online or blended learning and other characteristics as well as other outcome measures such as interest in course content, application of materials, satisfaction with materials, with flexibility in accessing them online, individualized support, or with self-paced learning. Thus far, adopting a blended learning format has proven to be an engaging and useful method to bring complex material to a diverse student class. Given that universities have rapidly pivoted to online delivery in this time of COVID-19, enhancing Blended Learning is increasingly urgent. Given this, our findings are also relevant to optimizing students' learning outcomes for these delivery methods. Finally, researching further enhancements will ensure that students are best equipped to apply these principles to their engineering practice, upon graduation.

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