Blended Learning in STEM and Non-STEM Courses: How do Student Performance and Perceptions Compare?

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Abstract
Examined in this study is the question of whether students in STEM courses perform better and have more positive perceptions than students in non-STEM courses, when both are offered in the blended format. As part of a blended learning initiative, 6 STEM and 8 non-STEM university courses were redesigned using the blended format. Students (n = 318) were surveyed on perceptions of their blended experience and courses grades were compared. Results indicated that STEM students performed significantly higher than non-STEM students; however, STEM students did not perceive their courses as positively as non-STEM students. The conclusion was that focusing blended learning course redesign in STEM fields in higher education may be advantageous, although more research is needed to confirm the findings and to investigate why student perceptions were relatively low for STEM students.

Keywords: STEM and non-STEM, blended learning, hybrid learning, student performance, student perceptions

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There is widespread recognition that undergraduate STEM (Science, Technology, Mathematics, and Engineering) pedagogy needs reform, yet there is a scarcity of literature on what instructional practices can bring about the necessary changes (Dolan, Lepage, Peacock, Simmons, Sweeder, & Wieman, 2016). A promising approach to transforming STEM instruction is blended learning, an instructional model that combines face-to-face instruction with online activities. Researchers have shown that across the higher education curriculum more broadly, students in blended courses appear to perform better and have lower dropout rates than traditional lecture approaches or fully online learning (Moskal, Dziuban, & Hartman, 2013). Moreover, there is emerging evidence that STEM students may be able to benefit more from the affordances of blended learning than non-STEM students as compared to face-to-face learning (Vo, Zhu, & Diep, 2017). As blended learning increasingly becomes the “new normal” in higher education (Dziuban, Graham, Moskal, Norberg, & Sicilia, 2018), the intriguing question arises of whether students in STEM courses perform significantly better than those in non-STEM courses, when both are offered in the blended format. A related question is whether there are differences in perceptions between students in blended STEM and blended non-STEM courses. This question is of relevance because there is evidence that student perceptions of blended courses relate positively to performance (Owston, York, & Murtha, 2013), and because no research has been reported that compares students’ perceptions of blended courses across both disciplinary fields. Therefore, in this study, we compare blended STEM and blended non-STEM courses on student performance and perceptions of learning in a blended course. Before considering the literature on performance and perceptions, two key concepts in this study, blended learning and STEM, need to be clarified.

Blended learning is not a well-defined concept. There is consensus in the literature that, at a minimum, blended learning is the combination of face-to-face and online instruction (Graham, 2006). Beyond that, conceptions of blended learning differ. The U.S. Department of Education defines it merely as the substitution of some in-class time with online time (Parsad & Lewis, 2008), whereas the former Sloan Consortium (now the Online Learning Consortium) is more precise by specifying that between 30% and 79% of in-class time is substituted by online time (Allen & Seaman, 2003). Means, Toyama, Murphy, and Baki (2013) found, in their extensively cited work, that many of the studies chosen for inclusion in their meta-analytic comparison of blended and face-to-face modalities reported that more time was often spent in blended courses than in the traditional face-to-face versions. The latter tends to happen when instructors add an online component to their traditional course, sometimes resulting in what has been called “a course and a half” syndrome (Garrison & Vaughan, 2008, p. 202). To avoid this difficulty, the authors argue that blended learning requires a fundamental redesign of a course, in which decisions are made about which mode is best suited to achieve specific student learning outcomes, without prior consideration of the proportion of time to be spent in either mode. Such a redesign often results in what Graham (2006) calls a transformational blend where “learners construct knowledge through dynamic interactions” (p. 13). According to Graham, more common in higher education, however, are enabling blends that result in greater access to or flexibility in learning by providing essentially the same learning opportunities as the traditional version of a course but through different modalities, or blends that only modestly enhance the learning experience by creating additional online resources or experiences.

There is no clear consensus on the definition of STEM either. The term came into prominence at the beginning of the twenty-first century, when there was a fear in the U.S. that the country was not producing enough science, technology, engineering, and mathematics graduates to remain competitive in the global economy (Breiner, Harkness, Johnson, & Koehler, 2012). Use of the term then rapidly spread around the world as other nations began setting STEM education as a priority. The concern in the U.S. led to calls for improving K12 science and mathematics education and increasing the number of college and university graduates in the STEM fields. An area of disagreement in the literature is which subdisciplines STEM encompasses. Some researchers and government reports restrict STEM to include only the four defining fields of study. For example, in reporting U.S. postsecondary STEM enrollment, Chen (2009) limited the definition to mathematics, natural sciences (including physical sciences and biological/agricultural sciences), engineering/engineering technologies, and computer/information sciences. On the other hand, in addition to these four core disciplines, the U.S. National Science Foundation uses a broader definition that recognizes life sciences (e.g., health professions/related clinical sciences, rehabilitation/therapeutic services, and nursing) and some social sciences (e.g., anthropology, economics, psychology, and sociology) as part of STEM (Green, 2007). Also in dispute is whether STEM is a multidisciplinary field where the four disciplines work together, yet retain their distinct disciplinary identity, or whether STEM is a new interdisciplinary or transdisciplinary field that emerges in between or beyond individual disciplinary commitments (Shanahan, Burke, & Francis, 2016). Moreover, Breiner et al. (2012) found that even university faculty involved in multiple STEM projects and research centers did not have a common understanding of the meaning of the rubric. Despite the general lack of agreement on the meaning of STEM, research into approaches that foster improvements in STEM teaching and learning are clearly desirable (Brown, 2012).

Conceptual Framework

Our study is framed by the literature on learner performance in blended courses in higher education, as well as their perceptions of learning in the blended model. These two fields are reviewed next with particular reference to STEM education.

Performance in Blended Courses Overall

There is substantive evidence in the literature that, on the whole, students in blended courses tend to modestly outperform their counterparts in traditional face-to-face courses. Evidence of this comes from ongoing seminal research carried out at the University of Central Florida involving nearly one million students (Moskal et al., 2013). This research indicates that across many different disciplines, students in blended courses have a higher success rate and lower withdrawal rate than those in nonblended courses. Six major meta-analyses of higher education research published between 2005 and 2018 also support this contention (Bernard, Borokhovski, Schmid, Tamim, & Abrami, 2014; Çirak Kurt, Yildirim, & Cücük, 2018; Means et al., 2013; Spanjers et al., 2015; Vo et al., 2017; Zhao, Lei, Yan, Lai, & Tan, 2005). Taken together the meta-analyses comprised a total of 583 individual effect sizes and with a median effect size of $g^+ = 0.37$ favoring blended learning, ranging from a low of 0.33 (Bernard et al., 2014) to high of 1.04 (Çirak Kurt et al., 2018). This median effect size suggests that 60% of students in traditional courses were below the mean of blended learning students, and it would be categorized by Cohen (1988) as between a small- and medium-sized effect.

Performance in Blended STEM Courses

With respect to blended learning in STEM courses, Vo et al.'s (2017) major study of 51 effect sizes found that blended STEM courses had an effect size that was over twice the magnitude of non-STEM courses when compared to traditional classroom-based courses (STEM $g^+ = 0.496$, non-STEM $g^+ = 0.210$). Vo and colleagues suggest that the difference between the two fields may be due to the more hierarchical structure of knowledge in STEM disciplines, which makes those disciplines more amenable to the linear nature of commonly used learning management systems. The advent of more advanced technological tools to support STEM, such as virtual labs and simulations, than non-STEM learning is another reason given. Additionally, the researchers suggest that because non-STEM pedagogy relies more heavily on dialog, non-STEM instructors have to make more significant adjustments to their pedagogical practice than STEM instructors, as there is a greater need for them to be present in and to facilitate online discussions.

We examined the studies with the two highest effect sizes (Melton, Bland, & Chopak-Foss, 2009; Day & Foley, 2006) and the two lowest (Choi, 2013; Schunn & Patchan, 2009) included in Vo et al.'s (2017) meta-analysis, to distinguish what may explain the differences in performance outcomes of the four studies. Table 1 provides an overview of the four studies. All four were carefully designed and executed studies that took place over an entire semester in different STEM disciplines. Online activities of all four centered on video recordings of lecture content, although the studies with the two highest effect size studies reported having online activities designed to engage students with the videos rather passively viewing them. All four studies devoted in-class time to discuss the videos and take part in other kinds of active classroom learning. The most striking difference between the high and low studies appears to be the reduction of face-to-face time in lieu of online activities—the two highest had a 50% reduction, while in the Choi (2013) study there was no reduction in face-to-face time (Schunn & Patchan, 2009, did not report any alteration of time). There is some evidence in the literature that performance tends to be higher in courses with as much as 50% or greater time online (Bernard et al., 2014; Means et al., 2013; Owston, York, & Malhotra, 2018; Zhao et al., 2005). We concluded that the greater amount of time online, as well as more structured and interactive online activities, might be the explanation for the differences between the high and low studies effect size studies in Vo et al.'s meta-analysis.

Several more recent studies also favored blended learning over traditional classroom instruction in STEM disciplines. Evident in these studies is the importance not only of content being available online, but the opportunity for immediate feedback on the content, either in class or online. For example, Bazelais and Doleck (2018) found that students in a blended college-level physics course significantly outperformed their peers in a traditional lecture course. The students in the blended section viewed web-based videos and followed up with discussions about the content with peers in the classroom. Hill, Chidambaram, and Summers (2017) compared students in a computer networking course that blended face-to-face classes with online lectures and discussion to a traditional version. They found the blended students achieved very significantly higher than the traditional group. Thai, De Wever, and Valcke (2017) examined performance of students in an invertebrates course in three modes: traditional, fully online, and blended. The fully online section had web-based lectures, online guided questions, and delayed feedback from the instructor. The blended courses were offered in two ways: the first was in-class lectures with online guided questions and delayed feedback on the questions from the instructor; the second had web-based lectures with guided questions in the classroom and immediate instructor feedback. Although the study was conducted over only 6 weeks with a relatively small sample ($N = 90$), the latter group significantly outperformed the fully online and traditional groups with large effect sizes. There were no significant differences between the two blended conditions; however, the first blended condition was significantly higher than fully online learning but no different than traditional learning. The study highlights the importance of having significant content available online (e.g., web-based lectures) and the importance of immediate feedback to consolidate student learning. In contrast, a study by Goode, Lamoreaux, Atchison, Jeffress, Lynch, and Sheehan (2018) found that students in a blended psychology statistics course performed significantly lower than face-to-face counterparts, although the effect size was negligible. Of interest in this study was that blended students spent 50% of class time only viewing online videos without interacting with peers or the instructor. To this point, Castaño-Muñoz, Duart, & Sancho-Vinuesa (2014) found in a large-scale study that one of the main reasons why students perform better in blended courses is because of online interaction with peers and instructors, rather than only passively viewing content.

Table 1

Comparison of Factors in Studies with Highest and Lowest Effect Sizes in Vo et al. (2017)

Factors	**Most significant effect size studies**		**Least significant effect size studies**	
	Melton et al. (2009)	Day & Foley (2006)	Choi (2013)	Schunn & Patchan (2009)
Sample size	251	46	73	81
Effect size	2.879	1.160	-.117	-.705
Research design	Pre-post; quasi-experimental; random selection of 3 blended and 1 traditional section	Matched control and blended classes	Random assignment to control and blended class	Partial random assignment to control or blended class
Discipline	General health	Human-computer interaction	Software engineering	Philosophy: Logic & Proofs
Reduction in face-to-face time	50%	Approximately 50%	None	Not reported
Online activities	Narrated PowerPoint presentations with corresponding note sheets, homework assignment, a quiz each week, and online discussions	Web-based lectures with slides and compulsory synthesis questions	Self-study of videos of course content	Not reported
In-class activities in blended section(s)	Brief lectures, discussions, group projects, presentations	Online lectures discussed in class.	Discussions, software development, and more feedback than control group	Not reported
Duration of course	One semester	15 weeks	15 weeks	One semester
Instructors	Different instructors	Same instructor for control and treatment groups	Not reported if the same or different instructors were used	Not reported if the same or different instructors used

Perceptions of Blended Courses Overall

Annual surveys of the EDUCAUSE Center for Applied Research consistently indicate that, on the whole, a large majority of students prefer to learn using a combination of online technology and face-to-face classes: about three-quarters prefer learning in both modes, while the remaining students are about equally split between preferring to learn only online, only face-to-face, or have no preference (Brooks, 2016). Other studies have found similar levels of preference for learning in the blended mode (Dziuban, Hartman, Juge, Moskal, & Sorg, 2006; Owston, Garrison, & Cook, 2006, Vargas-Madriz & Nocente, 2016). Spanjer et al.'s (2015) meta-analysis of 30 individual studies found a smaller, yet significant, preference among students for blended learning ($g^+ = .11$, $p < .05$). Among the reasons cited in the literature for students' favorable perceptions of blended learning are: flexibility, convenience, and reduced travel time, while retaining some face-to-face interaction (Moskal et al., 2013; Owston et al. 2013); more clarity in course expectations (Lim, Morris, & Kupritz, 2007); a feeling of intimacy and connection with the instructor through watching online videos (Vargas-Madriz & Nocente, 2016); higher perceptions of teaching effectiveness and course meeting expectations (Forte & Root, 2011); and readily adapting successful learning strategies in traditional courses to blended courses (Kumrow, 2007). Research also suggests that upper-year students are more engaged with blended learning than first-year students (Vargas-Madriz & Nocente, 2016), and that high-achievers view it more positively than low-achievers (Owston et al., 2013). However, undergraduate students generally favor blended learning more than graduate students (Castle & McGuire, 2010).

Perceptions of Blended STEM Courses

We could not find any published research comparing perceptions of students in blended STEM courses to those in blended non-STEM courses—one of the areas in which our research focuses—yet there is research that examines views of students in blended STEM courses with those in traditional lecture-based STEM courses. Similar to the general literature on student preferences for blended learning, this literature also suggests that STEM students prefer blended learning over traditional learning. For example: in science, Bazelais and Doleck (2018) found very high satisfaction (95%) in their blended physics course; in technology, Uzun and Senturk (2010) reported significant positive attitudes in computer usage course for teachers; in engineering, Rahman (2017) found that student satisfaction in a blended fluid mechanics course increased by 18% compared to the traditional version; and in mathematics, and Owston, Sinclair, and Wideman (2008) reported improved attitudes towards the mathematics and science by teachers who participated in a blended professional development program. Other studies in STEM disciplines indicate similar positive student perceptions of blended learning: Melton et al. (2009) in health; Gundlach, Richards, Nelson, and Levesque-Bristol (2015) in statistics; and Lian and He (2013) in biology.

Hence, there is a substantial body of evidence of students favoring blended learning over traditional learning in both non-STEM as well as STEM disciplines. Whether students have different preferences when studying in blended courses in one disciplinary area over the other disciplinary area is unclear.

Research Questions

As just outlined, there is a substantial body of research that examines student performance and perceptions of learning in blended STEM and blended non-STEM courses relative to face-to-face courses. None of this research directly addresses the question of how performance and perceptions compare when *both disciplinary fields are taught in the blended mode*. Thus, we chose to address this gap by investigating the following two questions:

1. How does student performance in STEM and non-STEM courses compare when both are taught in the blended mode?
2. How do student perceptions of blended learning in STEM and non-STEM courses compare when both are taught in the blended mode?

Methods

Setting

We investigated the above research questions at a large urban university in Canada with a very diverse student population. Prior to the beginning of the study, the university embarked on a major academic innovation initiative, an aspect of which was to provide funding to faculty to incentivize them to redesign their courses using the blended format. The 14 courses examined in this study were the first group of redesigned blended courses. An examination of the course descriptions indicated that six had a significant preponderance of STEM content to be classified as such using Green's (2007) more inclusive criterion, whereas the remaining eight were unambiguously non-STEM. The six STEM courses were: kinesiology (two courses), nursing (three courses), and psychology (one course). The eight non-STEM courses were: administrative studies (two courses), and one course each of anthropology, history, English, modes of reasoning, geography, and political science.

Course Design

Prior to the study all courses were offered in a traditional lecture format with no online component. All participating faculty received assistance in redesigning their course from the university's teaching and learning center and the instructional technology support team. The assistance was provided by a combination of workshops for all instructors and individual consultation and review of course designs. Biggs (2014) process of constructive alignment guided course design was used. By following this process, faculty and instructional designers attempted to create course learning objectives and activities that engaged students in higher level learning as much as practicable, and to ensure that the assessment procedures aligned with objectives and activities.

Table 2 provides a comparative overview of the key characteristics of the redesigned STEM and non-STEM courses. Instruction in both STEM and non-STEM blended courses was dominated by face-to-face teaching (50–70%). This teaching primarily involved the combination of traditional lectures led by the instructor and small-group seminars or tutorials facilitated by graduate teaching assistants. Students spent the remaining 30% to 50% of the time working online in the Moodle learning management system at a time and place that was convenient for them. Within Moodle students were provided with a variety of learning activities, such as group discussions, opinion polls, knowledge quizzes, collaborative wiki writing, and real-time chat. They could also access course learning resources and, in some cases, recorded lectures.

Both STEM and non-STEM courses employed online discussion forums. Students were typically assigned to discussion subgroups to respond to course-related questions and problems. Those discussions often represented an exchange of ideas, opinions, and solutions, and students were assessed on their ability to participate and contribute to the collaborative discourse.

Assessment procedures were typical of what one might expect in the two different disciplinary areas. STEM instructors focused primarily assessing student learning of the facts, principles, and concepts of the discipline, including the application and synthesis of this learning. On the other hand, assessment schemes for non-STEM courses were built around making connections and application of knowledge through critical and creative thinking. Examples of those assessments included individual and collaborative assignments that allowed students to synthesize knowledge, reflect on their experiences, write an essay response, or an opposing opinion on a controversial issue. The final course grade in both disciplines comprised of a combination of assignments, tests, and a final exam.

Table 2

Summary of Blended Learning Conditions in STEM and Non-STEM Courses

Blended learning conditions	STEM courses (*n* = 6)	Non-STEM courses (*n* = 8)
Subject areas	Kinesiology (2), nursing (3), and psychology	Administrative studies (2), anthropology, history, English, modes of reasoning, geography, and political science
Course duration	13 weeks	13 weeks
In-class activities	Lectures/seminars (50-70% course time), lecture recordings (or lecture slides with notes) posted to Moodle	Lectures/seminars (60–70% course time), lecture recordings (or lecture slides with notes) posted to Moodle
Online activities	Interactive activities such as discussions, polls, quizzes, wiki, and chat (30–50%)	Interactive activities such as discussions, polls, quizzes, wiki, and chat (30–50%)
Instructional design approaches	Participatory, collaborative learning together with self-directed asynchronous learning activities	Active learning and problem-based learning together with self-directed asynchronous learning activities
Grade assessments	Quizzes, midterm tests, and final exams that assessed foundational knowledge and to some extent application of concepts. From 10%–50% of assessments administered online, including individual assignment submissions. Median grade weighting for online discussions was 7%.	Essays, case studies, observations, reflections, collaborative assignments, and final exams that assessed application of concepts more than foundational knowledge. From 30% to 35% of assessments administered online, including individual assignment submissions. Median grade weighting for online discussions was 15%.

Procedure

The university's human subjects research ethics review committee approved the study. All 14 faculty members agreed to allow their students to participate. Students were informed that their course would be offered in a blended format through each department's mini-calendar. Moreover, when they enrolled in their course, they had to select a unique section code that designated a course as blended. How well students took note of these two warnings is not known.

A member of the research team visited each classroom toward the end of the course to explain the study and seek students' voluntary and anonymous participation. All students in attendance agreed to take part. Students were given a paper questionnaire with bubble answer sheets to assess their perceptions of their learning experience in a blended class as compared to traditional courses they had taken. The questionnaire was adapted from Owston et al. (2013) who reported a Cronbach's alpha of 0.908. It consisted of 13 questions that used a 5-point Likert-style scale (Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree), with 1 representing Strongly Disagree and 5 representing Strongly Agree. We obtained 300 complete questionnaire response sets (STEM $n = 155$, non-STEM $n = 145$). At the end of the questionnaire students were asked to provide open-ended written comments about their experiences in their blended course. A total of 145 sets (STEM $n = 111$, non-STEM $n = 34$) of written responses were obtained and transcribed.

Student performance was defined in this study as final course grade. A total of 318 grade sets (STEM $n = 161$, non-STEM $n = 157$) were obtained from the registrar's office. A grade set consisted of a student's final grade and cumulative grade point average (GPA). Grades were based on a 10-point scale ranging from 9 representing A+ (exceptional) to 0 representing F (failed).

Data Analysis

To address the first research question about performance, a one-way ANCOVA design was used with final course grade (GRADE) as the dependent variable, the cumulative grade point average (GPA) as the covariate, and discipline (STEM vs. non-STEM) as the independent variable. For this analysis and the analyses below, two-tailed significance tests were used.

We addressed the second question about perceptions with a convergent mixed-methods design that merged the questionnaire Likert scale results (quantitative) with the open-ended student comments (qualitative) (Creswell & Plano Clark, 2018). The purpose was to obtain a better understanding of why STEM and non-STEM students may have perceived their experiences differently than would have been possible with either quantitative or qualitative data alone. For the quantitative analysis, a one-way MANOVA design was used with the 13 questions as dependent variables and discipline (STEM and non-STEM) as the independent variable. Follow up univariate F tests were then carried out to determine if there were any significant differences between the two groups on any of the questions. The MANOVA design was used to avoid cumulative type I error that can occur if multiple univariate F tests were conducted first. For the qualitative analysis, the transcribed open-ended responses were coded using the themes of the 13 questions as categories. Summary statistics were then generated on the frequency of occurrence of the categories for STEM and non-STEM student responses.

Results

Research Question 1 Student Performance

The estimated marginal mean of the STEM students was 6.85, $SE = .090$, and the estimated marginal mean of the non-STEM students was 6.46, $SE = .091$. This difference was significant, $F(1, 317) = 8.92$, $MS = 10.97$, $p = .003$, thus the STEM students outperformed the non-STEM students. The partial eta squared effect size obtained by SPSS was $\eta^2 = .028$, which when converted to the more common Cohen's d is 0.340. A value of d between 0.2 and 0.5 is generally considered to be a small effect. Our finding is marginally smaller than the median effect size of 0.37 favoring blended learning calculated by Owston, York, and Malhotra (2019) across six separate meta-analytic studies, in which performance in blended and lecture courses was compared.

Research Question 2 Student Perceptions

Quantitative Analysis. A significant difference was found between STEM and non-STEM students on their perceptions of blended learning, Wilks' Lambda $\Lambda = 4.63$, $p < .001$, partial eta squared $\eta^2 = .174$. Follow up ANOVA tests for each of the 13 questions indicated that non-STEM students rated questions significantly higher (i.e., more favorably) than STEM students on all but three items. Effect sizes for the questions on which non-STEM students scored significantly higher ranged from small to medium as indicated by partial eta squared, with the largest effect being for Q8, which concerned the online and face-to-face components enhancing each other ($\eta^2 = .088$), and the smallest for Q7 about taking another blended course in the future ($\eta^2 = .024$). (These two effect sizes are equivalent to $d = .621$ and $d = .314$ respectively.) The non-significant results were for Q1 (Improved understanding), Q12 (Overwhelmed), and Q13 (More time and effort). Provided in Table 3 is an abridged version of each question and a summary of the analysis.

Table 3

Follow-up ANOVA Analyses for Survey Question

	Dependent Variable	**Mean STEM**	**Mean Non-STEM**	***F***	**Sig.**	***η*²**
Q1	This course has improved my understanding of key concepts	3.52	3.74	3.742	.054	.012
Q2	Amount of my interaction with the instructor increased	2.81	3.35	18.074	.000*	.057
Q3	Quality of my interaction with the instructor was better	2.96	3.47	16.830	.000*	.053
Q4	I feel connected with other students	2.66	3.26	20.945	.000*	.066
Q5	Quality of my interaction with other students was better	2.80	2.80	19.663	.000*	.062
Q6	I am satisfied with this course	3.61	4.14	22.992	.000*	.072
Q7	I would take another blended course in the future	3.63	4.01	7.216	.008*	.024
Q8	Online and F2F components enhanced each other.	3.22	3.88	28.611	.000*	.088
Q9	I am more engaged in this course	3.05	3.55	13.186	.000*	.042
Q10	I am likely to ask questions in this course	2.95	3.56	26.875	.000*	.083
Q11	Amount of my interaction with other students increased	2.75	3.44	24.910	.000*	.077
Q12	I am overwhelmed with information and resources	2.69	2.65	.099	.754	.000
Q13	This course required more time and effort	2.86	2.97	.629	.428	.002

*$p < .05$

Qualitative Analysis

The goal of the qualitative analysis for research question two was to see if the open-ended comments on the questionnaire could illuminate our quantitative finding that non-STEM student perceptions were more favorable overall than STEM student perceptions on the Likert items. Because students were free to comment on any aspect of their course meant that some topics covered by the questionnaire were addressed more often than others and some additional issues were introduced. We first report on the comments related to questions with the largest and smallest effect size where the means were significantly different, as these are most relevant for assessing whether the quantitative differences were supported by student comments. Then we report on the three items where no significant difference was found, to see if the qualitative data indicate any differences between the two student groups. We conclude by summarizing student comments on an emergent theme that was not directly related to any of the 13 questions.

Largest and Smallest Effect Sizes. With respect to the item with the largest effect size Q8 (Online and face-to-face components enhanced each other), ample qualitative evidence was found to support our quantitative finding. A total of 33 comments of the total 145 comments obtained were made on this topic. Of these, 15 (45%) were negative comments from STEM students and only 4 (12%) were negative from non-STEM students. Of the 14 remaining positive comments, only 4 (12%) came from STEM students, while 10 (30%) came from non-STEM students. The negative comments from STEM students typically focused on a dislike of the online component, including the discussion forums and the work required to participate in them. Said one STEM student: "I think the online forums are very time consuming and hard to follow. I find in-class discussions much more helpful." Positive comments from non-STEM students generally suggested that they were able to learn better because of the mix of the online and face-to-face components. For example, a non-STEM student said: "I really liked this course. The layout in-class/online has been very useful and helpful in my overall learning for its first time since coming here [to the university] I am able to get A's and B's [grades]."

As for Q7 (Taking another blended course) where the smallest effect size was found for significantly different means, only 4 comments were made on this topic. Of these, 2 were negative from STEM students and 2 were positive from non-STEM students, which provided very limited evidence to support the quantitative finding for this item. Online isolation was cited by the two STEM students for not wanting to take another blended course. Said one of these students: "This class (online portion) felt isolating. I would do a blended course again but would prefer to avoid it." Whereas the two non-STEM students said they would take a blended course again because of the inherent advantages of the model. One of them said: "Course was amazing. I actually enjoyed not having to come to class every week and being able to save money. The online video lectures were just as effective as in class lectures. Definitely would take a blended course like this again."

Non-significant Items*.* STEM students gave more negative comments than non-STEM students on topics related to the three non-significant items: Q1 (Improved understanding), Q12 (Overwhelmed), and Q13 (More time and effort). This suggests that, even though the null hypothesis could not be rejected, STEM students were generally less positive on these items as well. By coincidence with Q8, 33 responses were also coded for Q1. Of these, 17 (52%) were negative comments from STEM students and only 7 (21%) were negative from non-STEM students. Of the 9 remaining positive comments, 5 (15%) came from STEM students and 4 (12%) came from non-STEM students. The STEM students' comments focused for the most part on their preference to learn from face-to-face instruction rather than on a dislike of online work. One STEM student said: "I learned the most from hearing my professor speak and via the presentations. I also prefer learning from my professor in class." Another STEM student commented: "I feel that the course needed more face-to-face class time to really understand the course material." The positive comments were about students' ability to learn better because of online lectures and the flexibility of the blended mode. For example, a STEM student said succinctly: "Enjoyed flexibility and availability to watch/listen to lectures;" a non-STEM student commented: "Overall this course is good for me and the face-to-face classes blended with online have made this course worthwhile for me."

Eight STEM and no non-STEM students commented on the topic of being overwhelmed with the course (Q12). Students cited the amount of online materials and the discussion forums as being burdensome. A very illuminating yet typical comment was:

> Online discussions are overwhelming. Due to the number of students enrolled, it's very difficult to keep up with a discussion that has over 50 posts. There should at least be a time limit so discussions do not go on forever. It's also difficult to keep up with all the articles and videos being posted. You literally have to check Moodle multiple times a day.

This comment suggests that either the instructor had not anticipated the online workload of students or that the student misunderstood the expectations for the online component.

For the third non-significant question, Q13 about the course requiring more time and effort, 11 STEM students commented on the topic with all of them agreeing that it does. Again, students (8 STEM and 3 non-STEM) were critical about the online workload. Stated one STEM student: "I felt that there was too much time away from class. Having to follow discussions online became difficult because there was so much to follow and navigate through." A non-STEM concurred: "I strongly disagree with this type of learning. It is quite hard and [more] difficult than normal classes. I would like [only] face-to-face classes along with a recording of the lecture."

The same trend of non-STEM students being more positive held for the 8 remaining questions, however very stark differences were found on two of them. The first was Q9 (More engaged in this course) which had a total of 39 comments. Of these 34 (87%) were from STEM students, with 25 (74%) being negative and 9 (26%) being positive. Most STEM students felt that they just could not get engaged in the online portions of their blended course, regardless of whether it was viewing lecture recordings or participating in online forums, and they favored traditional lectures more. One STEM student summed this up by stating:

> I found that I was hard for me to pay attention when online and often couldn't commit to listen to the whole thing or anything at all. I would rather be in class because then I pay more attention and feel more engaged even though the commute is a waste of time; the experience in class is worthwhile.

Another one said: "I think the online forms (sic) are very time consuming and hard to follow. I find in-class discussions much more helpful." Ambivalence was expressed by a STEM who was able to benefit from online learning, but still preferred lectures:

> I did like the online portions of the class. I'm a shy person so I didn't usually participate in class. It allowed me to participate in discussions. However, I did feel that I did not learn a lot through the online portion. I learn more through face-to-face lectures. My suggestion is to have more face-to-face lectures than online lectures.

Only 5 comments were made by non-STEM students, 3 negative and 2 positive. The negative comments echoed the same sentiments as the STEM students. The two positive students were also ambivalent, reflecting engagement in the online components, but expressing concern about having too many online activities.

The second area with a large difference in the number of comments was Q5 (Quality of interaction with other students). A total of 23 comments were made with 16 (80%) being negative comments from STEM students and 2 (9%) from non-STEM students. STEM students did not find the online portion conducive to interaction. Stated one of them: “I felt that many students made unnecessary comments due to the participation mark online, thus the quality of the conversations suffered.” Another wrote: “I strongly did not like the online discussion forum and the fact that we had to post 4 times on it per week. I did not learn much at all from the online forums and they were a waste of time.” This was in sharp contrast to a one other STEM student who expressed a minority positive viewpoint: “I am enthusiastic about learning about opinions of other students in the course during online discussions.”

Emergent theme. Lastly, one theme was found that was not directly related to the 13 Likert questions—a specific dislike for learning in the blended mode. A total of 36 of the 145 students who commented expressed this view. Consistent with the findings above, STEM students were the majority, with 28 of the 36 (78%) commenting and only 8 (22) non-STEM students commenting on this theme. Students were blunt in many of their comments, such as these two STEM students who did not provide a reason for their opinions: “I am not a big fan of blended courses;” “I did not like the fact that this course was blended.” Several STEM and non-STEM students were more specific why they did not like blended courses stating that it was either because of the extra workload or that they simply can learn better in person. Two STEM students expressed the view held by others as well about not liking hybrid nature of blended courses but being happy with either fully face-to-face or fully online: “Hated this class format with in-class and online discussion. Do one or the other;” “I find that I learn better when a course is delivered in one format rather than some as an in-class lecture and some online. However, I learn best when I can learn independently [online].” This finding underscores the fact that not all students are going to be satisfied learning in the blended mode.

Discussion

In this study, we compared student performance, as measured by final course grade, and perceptions of their experience learning in a blended environment in six STEM and eight non-STEM blended courses. We found that STEM students out-performed non-STEM students on final course grade after adjusting for prior academic attainment using GPA as a covariate. The resulting effect size of $d = 0.37$ was relatively small yet still pedagogically meaningful. It implies that 64 % of the STEM students were above the mean of the non-STEM students. This effect occurred despite the well-recognized phenomenon that students tend to be graded harder in STEM courses (Kokkelenberg & Sinha, 2010). Moreover, our findings are consistent with research comparing student performance in blended and traditional lecture formats across a variety of disciplines, which suggests that, on the whole, students perform better under blended conditions with a small to medium effect size (Bernard et al., 2014; Means et al., 2013; Moskal et al., 2013; Spanjers et al., 2015). Moreover, the results support the conclusion of Vo et al. (2017) who that found both STEM and non-STEM students in blended courses perform better than students in traditional courses, although STEM students benefit most from blended courses.

As for possible explanations for our findings about performance, Castaño-Muñoz et al. (2014) suggest that higher quantity and quality of interaction is the chief explanation of why blended students perform better than students in traditional classes. Our study does not support this hypothesis as STEM students scored significantly lower on the four questions dealing with the quality and quantity of interaction with fellow students and the instructor (Q2, Q3, Q5, and Q11). Thus, we are left to conclude that it may well be the more linear, hierarchical structure of knowledge in STEM disciplines (Donald, 2002) that may make them more readily adaptable to the online component of blended courses. Additionally, because STEM students tend to be more linear thinkers, they would likely be more comfortable to learn online, and the linear structure of the learning management system may be better able to support them in their learning (Vo et al. 2017).

What is surprising about our findings is that even though STEM students performed better, they perceived their blended courses less positively than non-STEM students. STEM students' responses to our questionnaire were significantly lower than non-STEM students on all but three questions, and on those three questions there were no significant differences between the groups. Our qualitative analysis of student open-ended comments supported the questionnaire results showing that non-STEM students were more positive. Moreover, even on the three questions where no significant differences were found, comments suggested that non-STEM students were more positive in terms of blended learning improving their understanding (Q1), being less overwhelmed by course work (Q12), and their course not requiring more time and effort (Q13). These findings contradict Owston et al. (2013) who found that perceptions of blended learning are positively related to performance. We have not found any published research that has directly compared STEM and non-STEM students' perceptions when both disciplines are taught in the blended mode; however, as discussed earlier, students in both STEM and non-STEM disciplines perceive blended courses more positively overall than their counterparts in traditional courses (Bazelais & Doleck, 2018; Dziuban et al., 2006; Melton et al. 2009; Spanjers et al., 2015).

The reason why STEM students were less positive about blended learning despite their higher performance is not clear. The highest effect sizes in favour of non-STEM students were found for Q8 (Online and F2F components enhanced each other) and Q10 (I am likely to ask questions in this course), both of which deal with interaction. One explanation for this finding may be more that the non-STEM students enjoyed the opportunity for their voices to be recognized in class and online, even though this opportunity did not translate into higher performance. Alternatively, it may be that STEM students felt less positive because they lacked connection with their peers and their instructor.

Our study was not without limitations, however. This was quasi-experimental study in which the researchers were not able intervene to ensure that STEM and non-STEM students received identical blended learning experiences other than subject matter content. Courses were taught in a variety of academic specialties within these two disciplines by different instructors in different academic departmental contexts. Although we did not observe any substantive differences in the overall organization and delivery of the courses, they may have occurred. Nevertheless, there was no evidence to suggest that variations in course design and implementation within disciplines was any different than between disciplines. A second limitation is that we used the more comprehensive definition of STEM given by the National Science Foundation (Green, 2007) that includes life sciences and some social sciences. Different results may have been obtained if the study was restricted to the traditional four core STEM disciplines.

Conclusions

Our findings about performance imply that when embarking on blended learning course redesign initiatives, institutions may be wise to focus their initial efforts on the STEM fields. This finding comes at an opportune time as many universities are placing greater attention on STEM education and planning on spending more in these areas to improve instruction (Lederman, 2019). Thus, institutions may be able improve student learning outcomes, while at the same time, provide students with more flexibility in their programs of study through blended learning. Nonetheless, more research is needed to confirm our finding about performance by comparing blended courses in other STEM and non-STEM disciplines, to determine to what extent the finding is dependent on the classification of disciplines. In other words, if research focused only on blended courses in the core STEM disciplines rather than the more inclusive interpretation of STEM that we used, would the same findings be obtained? If not, are there particular STEM disciplines (e.g., mathematics) that may be more suitable for blended learning than others?

We are concerned that perceptions of STEM students were found to be less positive than their non-STEM counterparts. This finding is relatively robust as we had both quantitative and qualitative evidence to support the conclusion; nonetheless, research needs to be undertaken in other settings to validate this finding. A detailed analysis of interaction among students and between instructor and students would help shed light on this issue, as richer discussions are more likely to occur in non-STEM disciplines at the undergraduate level than in STEM disciplines by the very nature of the subject matter. This analysis should occur in both the online and face-to-face classes. Researchers may also wish to consider conducting focus groups or interviews to explore students' perceptions of learning in their disciplines. Such research would provide guidance to educators when designing both blended STEM and non-STEM courses.

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