Investigating the Impact of Blended Learning on Academic Performance in Higher Education

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Abstract

This dissertation consists of three chapters that contribute to the study of blended learning and academic performance. The importance of STEM education is well documented in the literature; however, many educators and researchers have expressed major concern regarding the present state of STEM education. To improve this situation, new pedagogies, such as blended learning have been proposed and researched. The last decade has seen an increase in the use of blended learning to support student learning and enhance engagement in STEM education; however, the effect of blended learning on teaching and learning remains unclear and often are mixed. The extant research has addressed the benefits and effectiveness of blended learning, as well as the impact of blended learning on academic performance, however, the findings suggest a lack of agreement on the nature of the relationship between blended learning and academic performance. Since the implementations of blended learning have become ubiquitous, it is imperative to understand their impact, especially on students' learning outcomes and achievement. To address these gaps in the literature, this dissertation, composed of three empirical studies, examines the relationship between blended learning and academic performance in a sample of pre-university CEGEP science students. Study 1 investigates the link between blended learning and academic performance—using a low-intensity blended context as a point of reference for the follow-on studies (Studies 2 and 3) in this multi-study dissertation. Study 2 examines the impact of frequent two-stage quizzes and peer formative feedback in blended learning situations on performance. Whereas study 3 examines the impact of asynchronous online video instructions with online homework & instant feedback in blended learning situations on performance. This research contributes to the literature by expanding on the understanding of how blended learning is linked to academic performance. The dissertation concludes with a discussion of the implications as well as avenues for future research.

Résumé

Cette thèse se compose de trois chapitres qui contribuent à l'étude de l'apprentissage mixte et des performances académiques. L'importance de l'enseignement des Sciences-Technologies-Ingénierie-Mathématiques (STEM) est bien documentée dans la littérature. Cependant, de nombreux éducateurs/éducatrices et chercheurs/chercheuses ont exprimé une profonde préoccupation concernant l'état actuel de l'enseignement des STEM. Pour améliorer cette situation, de nouvelles pédagogies, tel que l'apprentissage mixte, ont été proposées et étudiées. La dernière décennie a vu une augmentation de l'utilisation de l'apprentissage mixte pour soutenir l'apprentissage des élèves et ainsi améliorer l'engagement dans l'enseignement des STEM. Cependant, l'effet de l'apprentissage mixte sur l'enseignement et l'apprentissage demeure ambiguë et souvent mitigé. Bien que les recherches existantes aient porté sur les avantages et l'efficacité de l'apprentissage mixte, ainsi que sur l'impact de l'apprentissage mixte sur le rendement scolaire, les résultats suggèrent un manqué de lien sur la nature de la relation entre l'apprentissage mixte et le rendement scolaire. Étant donné que les mises en œuvre de l'apprentissage mixte sont devenues omniprésentes, il est impératif de comprendre leur impact, en particulier sur les résultats d'apprentissage et les résultats des élèves. Pour combler ces lacunes dans la littérature, cette thèse, composée de trois études empiriques, examine la relation entre l'apprentissage mixte et le rendement scolaire dans un échantillon d'étudiants sous-représentés en sciences pré-universitaires du CEGEP. L'étude 1 examine le lien entre l'apprentissage mixte et les résultats scolaires, en utilisant un contexte mixte à faible impact comme point de référence pour les études de suivi (études 2 et 3) dans cette thèse multi-études. L'étude 2 examine l'impact sur les performances des fréquents quiz en deux étapes et du feedback formateur des pairs dans des situations d'apprentissage mixte. L'étude 3 examine l'impact des instructions vidéo asynchrones en ligne avec les devoirs en ligne et le retour d'information instantané dans des situations d'apprentissage mixte sur les performances. Cette recherche contribue à la littérature en élargissant la compréhension sur la façon dont l'apprentissage mixte est lié au rendement scolaire. La thèse se termine par une discussion sur les implications ainsi que sur des pistes pour de futures recherches.

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Contributions of Authors

The dissertation is composed of three manuscripts— one published and the remaining two in preparation. As the primary author of this dissertation, I was responsible for the conceptual thinking, review, data collection and analyses, and writing included in the dissertation. My supervisor, Dr. Alain Breuleux, supported and mentored me during the dissertation process, and provided editorial comments and input on the dissertation.

- Chapter 1: Literature Review

Bazelais, P., & Breuleux, A. (2020). Investigating blended learning and its theoretical framework in higher education: A review (In preparation).

Contributors: I completed and wrote the literature review, which was submitted in partial fulfillment of the requirements for the comprehensive exam. Dr. Breuleux and Dr. Lajoie provided both inputs and guidance prior the writing of my review and Dr. Breuleux provided further inputs and editorial assistance during the writing and on the final review paper. Dr. Lajoie, as a committee member, provided comments on the final review paper.

- Chapter 2: Study 1

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• Chapter 3: Study 2 and 3

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Contributors: I conceptualized the studies in the dissertation, conducted the data collection and analyses, and wrote the full draft of the manuscripts. My co-authors provided editorial assistance on the manuscript drafts.

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Introduction

The prominence of STEM (Science, Technology, Engineering, & Mathematics) education (see Akiha et al., 2018; Ardianti et al., 2020; Bybee, 2013; Eagan et al., 2014; Hains-Wesson & Tyler, 2015; Koutsopoulos, 2019; Langdon et al., 2011; National Research Council (NRC), 2011; Owston et al, 2020; Watkins & Mazur, 2013) and the prevalence of information and communication technologies (ICT) have been recognized in the educational literature because of the essential roles they play in sculpting the knowledge economy, the workforce, and the technology industry. The STEM field plays a critical role in national security, global competitiveness, economic growth, and in building the foundational skills needed of the 21st century (Koutsopoulos, 2019; Langdon et al., 2011; U.S Bureau of Labor Statistics, 2009). STEM education is vital to our future and the workforce and remains the fastest growing sector of the economy. The STEM field is growing at 17%, while others at 9.8% (Koutsopoulos, 2019; Langdon et al., 2011), and is accountable for 6.2% of overall employment in the United States (Fayer et al., 2017). Despite the growing interests and significance placed on the STEM field by both educators and policy makers, the number of students pursuing STEM programs or completing their degree continues to be a major concern or challenge (Akiha et al., 2018; Eagan et al., 2014).

Given the ongoing concerns and challenges confronting the STEM fields—namely, poor instruction, lack of interest in STEM fields, declining rates of STEM degree production, lack of diversity, and high attrition rates (Akiha et al., 2018; Eagan et al., 2014; Hains-Wesson & Tyler, 2015; Watkins & Mazur, 2013)—researchers have increasingly sought for new pedagogical approaches and strategies to improve instruction, learning, and engagement in STEM education (Baldwin, 2009; National Research Council, 2011; Watkins & Mazur, 2013).

As calls for STEM education improvements intensify, many have turned to new pedagogical approaches and technology to improve learning outcomes and achievement. Consequently, the use of new technologies in 21st-century teaching and learning is a topical theme in education. Understanding how these technological tools can be used to foster more profound learning experiences is critical for improving instruction and learning in higher education, particularly, in STEM education. In response to this, many new pedagogical innovations have been researched and offered. One notable offering is the blended learning (BL) approach—the combination of face-to-face (FTF) classroom instruction with online-mediated instruction (Graham, 2006, 2009), which has received growing interest and attention from the education community (Bernard, Borokhovski, Schmid, Tamim, & Abrami, 2014; Boelens, Voet, & De Wever, 2018; Liu et al., 2016; Means, Toyama, Murphy, & Baki, 2013; Spanjers et al., 2015). Indeed, educators have increasingly turned to the use of blended learning, and new developments in the implementation and use of blended learning continue to be documented (Halverson et al., 2014; Vo, Zhu, & Diep, 2017).

Apart from the paradigm shift from teacher-focused to learner-centered pedagogy known as "constructivism" (Piaget, 1976; Vygotsky, 1978), in the 20th century, blended learning has become one of the fastest emergent area of scholastic uses of technology in the history of higher education (Allen et al., 2016; Means et al., 2013; Stockwell et al., 2015). A review of the extant literature reveals that authentic blended learning approaches enhance college students' learning and retention and the quality of instruction (Allen et al., 2016; Means et al., 2013; Stockwell et al., 2015). Furthermore, evaluation of evidence-based instructional practices such as those demonstrated to promote better learning outcomes (Bernard et al., 2014; Ginder & Stearns, 2014; Means et al., 2010, 2013; Tamim et al., 2011) in online learning suggest that the central features for cultivating student success are to design courses that augment student engagement or time-on-task. Researchers of online education have suggested that both the effectiveness and learning outcomes of blended learning are equal or better to the traditional FTF courses (Allen et al., 2016, 2017; Bernard et al., 2014; Means et al., 2013; Larson & Sung, 2009; Tamim et al., 2011). Likewise, 71% of administrators and online educators believe that the learning outcomes and effectiveness of blended learning courses are comparable or superior to the traditional FTF or fully online courses (Allen et al., 2016). Blended learning holds much promise for underperforming students, as they tend to improve student access through increased flexibility and convenience, can create a more positive and active learning environment, and has been suggested to enhance both pedagogy and achievement, especially in STEM education (Drysdale et al., 2013; Means et al., 2013; Spanjers et al., 2015; Stockwell et al., 2015). Whereas blended learning has been increasingly adopted in colleges in North America, it has received limited attention in the context of *Collège d'enseignement général et professionnel* (CEGEP—for a primer on CEGEPs, see Bazelais, Lemay, & Doleck, 2016) pre-university programs.

The CEGEP education system is primarily a post-secondary education system in Quebec, Canada, which serves as a gateway for pre-university science students who want to attend Quebec universities (Bazelais et al., 2016). The CEGEP education system is a 2-year pre-university science program composed of public and private and English and French colleges. Besides serving as an intermediary for university studies, CEGEPs also prepare students pursuing a trade or profession for the workforce via a three-year technical program leading to an Attestation of College Studies (AEC; Attestation d’études collégiales; Rocher, 2008). In Quebec, students intending to enroll in a Quebec university must pass through the

CEGEP system and obtain a Diploma of College Studies (DEC; Diplôme d'études collégiales). Although the CEGEP system is similar to the U.S community college system, it is unique to the province of Quebec in the sense that it is not a high school nor a university but equivalent of grade 12 and the first year of university. While the extant literature has grappled with understanding the relationship between blended learning and academic performance, however, the underlying tenet of this body of work suggest that the topic is not fully understood, and thus prompts for further research. This dissertation will address this gap by examining the effectiveness of blended learning and academic performance in the context of a different educational setting, namely, CEGEP pre-university science program.

Research has documented many potential affordances of blended learning, including but not limited to: flexibility in terms of place and time (Boelens et al., 2018); some degree of control over their own learning (Spanjers et al., 2015); increased attendance and satisfaction (Stockwell et al., 2015); improving attitudes towards subject matter (Lin, Tseng, & Chiang, 2016), engagement with content (McLean, 2018), and customizable experience (Cuesta-Medina, 2018). Importantly, several studies and meta-analyses have considered and illustrated the influence of blended learning on learner outcomes (Bernard et al., 2014; López-Pérez, Pérez-López, & Rodríguez-Ariza, 2011; Means et al., 2013; Schmid et al., 2014; Tamim et al., 2011; Vasileva-Stojanovska et al., 2015; Vol et al., 2017), mainly, in terms of academic performance as measured by factors such as overall course grades, GPAs, and gains in test scores (Drysdale et al., 2013), final marks (López-Pérez, Pérez-López, & Rodríguez-Ariza, 2011), and end-of-course evaluations or final course grades (Vo et al., 2017). Similarly, more research is needed to investigate the relationship between academic performance in the context of learner engagement, motivation, and satisfaction, more importantly, in the context of increased workload and time required on investment. While findings on comparison studies and meta-analyses suggest that blended learning improved learning outcomes over FTF and online conditions (Bernard et al., 2014; Drysdale et al., 2013; Means et al., 2013; Larson & Sung, 2009; Tamim et al., 2011; Vo et al., 2017), these meta-analyses and studies have varied parameters such as: (a) they include studies of both primary and secondary education systems; (b) contrast a large number of blended and traditional courses over long periods or different time intervals, and; (c) include older studies dating as far back as the mid-nineties to 2010. Consequently, various definitions may have been used to characterize blended learning (Spanjers et al., 2015). These previous meta-analyses mostly found small to medium range positive effect sizes for learning outcomes (Drysdale et al., 2013; Spanjers et al., 2015); however, the effects of increased workload, effort, and time may have confounded and biased the positive findings, thereby limiting the generalizability of the effects on learning outcomes. The researchers argue that both the prominence of technology and the infrastructure have since improved in schools, for example, increased accessibility, improved technological tools, videos and animations, and other types of multimedia are more readily available today than previously (Spanjers et al., 2015; Vo et al., 2017). Furthermore, the way in which blended learning is conceptualized and implemented in primary or secondary learning environment may be completely different from higher education or across disciplines. According to Friesen (2012), only blended learning definitions from 2006 and onward should be considered topical or germane. Accordingly, all these factors may have confounded consequences on the effectiveness of blended learning and how it is construed, and thereby, limit the overwhelming positive effects reported in these past studies and previous meta-analyses. Furthermore, these older studies, meta-analyses, and the various definitions may have had an adverse impact on the interpretation, design, and the implementation of the blended learning environment (Deperlioglu & Kose, 2013; Graham, 2013; Lee, Fong, & Gordon, 2013) and subsequently affect the effectiveness of blended learning on learner outcomes and student satisfaction (Spanjers et al., 2015). To better assess the effectiveness of blended learning and learner outcomes, more research and meta-analyses are needed, for example, future meta-analyses should only examine studies from 2010 to present, more importantly, they should differentiate between primary, secondary, and higher education, including using the most current definition and implementation of blended learning contexts.

While a myriad of research studies has documented and addressed, mainly, the definitions, methodologies, transformative potential, and several design approaches of blended learning (Garrison & Vaughan, 2008; Halverson et al., 2012, 2014; Hoic-Bozic, Mornar, & Boticki, 2009; McCarthy, 2010; Newcombe, 2011), relatively fewer research has tried to compare and identify their benefits (e.g., accessibility and convenience, opportunity, engagement, interaction, satisfaction, instructional design, self-regulated and directed learning, learning environment, and cost effectiveness) or shortcomings (e.g., increased work load, required effort and time on investment) on learning outcomes (Alammary et al., 2014; Drysdale et al., 2013; Graham, 2009, 2012; Spanjers et al., 2015). Furthermore, the lack of theoretical foundations or instructional pedagogical design and implementation for research (Drysdale et al., 2013) poses serious methodological challenges in the design, implementation, and application of blended learning. As argued by Moore (2005), there is “a disconnection between the empirical part of the research and the theoretical" (p. 127). Indeed, others suggest that a stronger relationship should exist between “theory building and practical application” (Saba, 2007, p. 52) of blended learning. Consequently, blended learning requires conceptual frameworks that must be specific to blended learning in order to help researchers and practitioners fully understand the complexity of how to effectively design and blend, more importantly, how to choose the right blending context.

Although findings on comparison studies suggest that blended learning improved learning outcomes (Bernard et al., 2014; Drysdale et al., 2013; Means et al., 2013; Larson & Sung, 2009; Tamim et al., 2011), the understanding of how and why is not entirely conclusive or understood, and thus warrants further research (Graham, 2013). While the extant literature provides some emerging understanding and critical findings of blended learning, some new questions emerge and prompt some openings for future research. For example, how and why blended learning is more effective than other forms of learning or modalities? How do instructional strategies, technology, or particular media impact learner outcomes? What design features could lead to greater student engagement, motivation, collaboration, satisfaction, and learner outcomes? How do various pedagogical stances, for example, increased workload, the amount of time student spend online, autonomy, self-regulation, and the purpose of technology moderate the effectiveness of blended learning on academic performance? Despite the positive effects of blended learning, there is still a gap, and further research is necessary to differentiate between the effectiveness of blended learning contexts and other approaches to learning. Understanding how to effectively design, develop, and use blended learning contexts to foster more profound learning experiences is critical for improving instruction and learning. Blended learning contexts that are designed and implemented with evidence-based instructional practices (e.g., interactive engagement or active learning strategies) have the potential to result in improved learner engagement, satisfaction, and achievement (López-Pérez, Pérez-López, & Rodríguez-Ariza, 2011; McLean, 2018; Means et al., 2013). Various research studies have concluded that collaborative learning such as interactive engagement or problem-based learning coupled with online-mediated instructions are useful teaching and learning approaches for engaging students in an online learning community (Keengwe & Kang, 2012; Stockwell et al., 2015; Yeh et al., 2011). They posit that online learning communities contribute to active and collaborative participation, knowledge formation, and increase learning experiences, achievement, and satisfaction.

The blended learning approach can be characterized as a social constructivist approach that supports and enhances student learning through diverse modes of instructional interactions, from collaboration, motivation and self-regulation, co-regulation and socially shared-regulation, to encouraging independence, and self-directed or self-paced learning (Barnard et al., 2009; Graham, 2009, 2012; Järvelä & Hadwin, 2013; Means et al., 2013; Keengwe & Kang, 2012; Stockwell et al., 2015; Yeh et al., 2011; Zimmerman, 2008). The online environment can enable students to assume greater control over the objectives, content, and progress of the learning process (Bernard et al., 2014; Järvelä & Hadwin, 2013). Blended learning has the potential to improve student access through increased flexibility and convenience as blended courses offer greater flexibility with regards to time, place, and pace, and provide better opportunities to underperforming students and to those who may not have access to FTF instruction. Blended learning holds much promise for underperforming students, as they can increase student engagement by creating a more positive and active environment, which has been shown to enhance both the quality of instruction and student learning outcomes (Means et al., 2010, 2013; López-Pérez, Pérez-López, & Rodríguez-Ariza, 2011).

Problem Statement

Current science education research suggests that the traditional FTF lecture-based instruction (teacher-focused) is less effective as a pedagogical means for teaching and learning as it tends to emasculate conceptual change and problem-solving abilities, and hence adversely affects learner outcomes in STEM education (Caldwell, 2007; Crouch & Mazur, 2001; Duncan 2007; Hake 1998). Although the traditional lecture-based instruction is less effective as a tool for teaching and learning, it continues to be the prevalent means of science instruction in higher education (Freedman, 2000). However, current research in science education argues that student-centered approaches such as interactive engagement (Caldwell, 2007; Hake, 1998) that actively construct new knowledge and meaning through mutually shared-understanding (Richardson, 2003, Hmelo-Silver & DeSimone, 2013) promote better learning experiences and learning outcomes in the college science classroom.

The importance of science, technology, engineering, and mathematics (STEM) has been widely acknowledged in a significant body of writing in both the educational literature and the media because of its essential role in shaping the knowledge economy and technical workforce of the future. However, struggling to complete introductory STEM courses can result in loss of confidence and motivation, eventually leading to a divergence away from STEM majors (Gasiewski et al., 2012). There are several reasons why traditional pedagogy has evidently become less effective in teaching science, for example: ineffective pedagogy, lack of teacher-student interaction or support, and loss of interest. This is problematic because high attrition rates faced by STEM majors remains a pressing problem (Chen, 2013) that affects the graduation rates in STEM and consequently the technical labor force. Furthermore, introductory science courses often fail to acknowledge students' prior beliefs, expectations, and misconceptions about science. For example, each student entering an introductory science course possesses a set of misconceptions, expectations, and intuitions about science concepts that are drawn directly from personal or prior real-life experiences—their views and beliefs about what it implies to learn and understand science—which affects how they approach a science course (Elby, 2001; Redish, 2002). However, these misconceptions and expectations that students bring to introductory science courses are often not addressed in traditional settings, and thereby, pose a significant roadblock or obstacle to learning new concepts or skills, which effectively determines how students construct meaning and understanding. These expectations, misconceptions, and intuitions impact what students learn and take away from the course, which can be utterly inconsistent with what the instructor expects. Accordingly, the combination of the misconceptions students brings to class, and the prevalence of teacher-centered pedagogies in science education has been linked to students' failure to understand fundamental science concepts (Duncan 2007; Freedman, 2000; Mazur & Watkins, 2010).

In the context of Quebec, the percentage of CEGEP students completing the two-year pre-university program within the two years is persistently low- 32%; further, less than 70% completed their CEGEP education within four years (SRAMP-PSEP, 2016). Likewise, 30% of CEGEP students are permanent dropouts, and 34% do not graduate within four years with the dropout rate being higher at 36% for males as compared to 25% for females (Report of The Action Group on Student Retention and Success in Quebec, 2009). Even more disturbing, 54% of male students drop out before obtaining a CEGEP diploma, a percentage that is more than double the national average of 22% (Statistics Canada, 2008).

Dropout of this enormity engenders considerable interpersonal, social, and financial costs for students, which may lead to higher unemployment, lower life expectancies, lower civic commitment, and lower overall income. Concomitantly, the dropout crisis results in loss of government revenue of $120,000 per dropout in the form of increased spending on social services, lost tax revenues, and additional costs on efforts to reintegrate students into the educational system and the technical labor force; consequently, an annual economic loss of $1.9 billion per cohort is incurred by Quebec society (The Action Group on Student Retention and Success in Quebec, 2009). To remain competitive, innovative, and sustainable in this knowledge-based economy, future research in STEM-related programs must address the problem of perseverance and academic achievement in these programs. Thus, investigations of dispositions that affect the quality of instruction and student persistence and achievement outcomes are both timely and deserving of attention.

Research Questions & Methodology

This study explores how a blended learning approach affects students' performance in and appreciation of STEM education, particular, in understudied pre-university population such as the CEGEP education system. Every student enrolled in the pre-university science program at the CEGEP, where the study was conducted, is required to take three compulsory courses in physics, namely, Mechanics, Electricity & Magnetism (E&M), and Waves, Optics and Modern Physics (Waves). Importantly, success in the latter physics courses (e.g., E&M and Waves) depends on a solid understanding of the underlying concepts introduced in the Mechanics course. Students who fail to grasp the fundamental concepts of Newtonian mechanics are usually ineffective in the subsequent E&M course. Therefore, it is imperative that students attain mastery of the fundamental concepts introduced in introductory science courses in order to be successful in STEM. It is suggestive that blended learning can create a more positive and active learning environment through increased engagement and time-on-task (Means et al., 2010, 2013) and subsequently help students achieve the necessary mastery by maximizing time dedicated to authentic problem-solving and deep conceptual understanding (Bergmann & Sams, 2012; Mazur, 2013).

As mentioned earlier, there has been a tremendous prominence ascribed to the transformative potential and the effectiveness of blended learning in higher education. Although findings on comparison studies suggest that blended learning improved learning outcomes and has the potential to increase student engagement by creating a more positive and active environment, findings from these studies were often mixed and of overall small to medium effect size, and derived from a variety of research designs and unique settings (Drysdale et al., 2013). In addition, some researchers argue that more research is needed to examine the effectiveness of blended learning in different educational settings, namely, pre-university student populations (Drysdale et al., 2013; Halverson et al., 2012; Spanjers et al., 2015) to better assess the state of blended learning and the generalizability of the overall findings (Spanjers et al., 2015). This dissertation will address these two important gaps. While a review of the extant literature reveals some growing appreciation and positive findings of blended learning, some new questions emerge and prompt some openings for further research. For example, what are the moderating factors for the effectiveness of blended learning? How do instructional pedagogical design, robust quizzes and peer formative feedback affect learner outcomes in blended learning contexts? Can a blended learning context result in higher performance on a standardized end-of-semester assessment such as a cumulative standardized final exam in a CEGEP science classroom? Although blended learning methods are significantly more effective, can enhance both the quality of instruction, and student learning outcomes in STEM education, little is known about how such instructional strategies and practices affect learner outcomes in the context of pre-university CEGEP science students. While the effects of blended learning continue to gain popularity and widespread acceptance in the educational landscape, very little research has been conducted on pre-university CEGEP STEM students in the context of the effectiveness of blended learning. The present study addresses these gaps by examining the effectiveness of instruction in the pre-university science program at CEGEP, comparing the blended learning context and the traditional FTF instruction, and asks whether a blended learning physics course that integrates evidence-based instructional practices and information communication technology (ICT) results in better student performance on a standardized end-of-semester assessment in all three physics courses of the pre-university science program. Consequently, the proposed research study intends to investigate the following essential question:

1) What is the link between blended learning and academic performance in pre-university science CEGEP students?

The dissertation research is comprised of three studies that will investigate the link between blended learning and academic performance in STEM education, particularly, in an understudied pre-university students population. The studies contrast between blended learning (treatment) and the traditional format (control) and draw on data from pre-university CEGEP science students in the following three courses: (a) Mechanics, (b) Electricity and Magnetism (E&M), and (c) Waves, Optics & Modern Physics (Waves). In all three of the studies, I am both the researcher and instructor in at least one of the conditions, for example, I am the instructor in both conditions (treatment and control) for study 1 and, for study 2 and 3, I am the instructor in only the treatment conditions. To avoid instructor bias, particularly in study 1, identical content, lecture slides, including three required unit tests and a blind standardized final exam (common to all sections) was used for study 1, as was in the case of study 2 and 3. In addition, many precautions were taken in study 1 to minimize instructor bias and to ensure that the two conditions were in fact equivalent according to course content, delivery, workload, and evaluations. For example, the supplemental online videos were made available to both conditions, except that it was optional for the control group. The cumulative blind standardized final exam, common to all sections was chosen out of a bank of eight final exams in the last week of the semester by a faculty member in the Physics department who was not teaching any of the sections, and group-marked by all members of the faculty teaching the course. The cumulative standardized final exam (for each of the studies) is three (3) hours long and administered at the same time for all the sections at the end of the semester, and consisted of 20 conceptual multiple-choice questions (20% weighted score), and 10-12 standard physics word problems (80% weighted score). Study 1 investigates the link between blended learning and academic performance in the context of teaching Mechanics using a low-intensity blended learning context— a course that add extra online resources (e.g., online lectures) to the traditional course structure without reducing any FTF meeting. Whereas Study 2 and 3 investigate the link between blended learning and academic performance in the context of teaching E&M and Waves using a medium-intensity blended learning context— the existing course outline is restructured by replacing some of the FTF elements with online learning where 30% to 79% of the course content is delivered online. The proposed research will contribute to expanding our understanding of how new instructional approaches, i.e., blended learning, can promote retention and better learning outcomes in understudied contexts such as the CEGEP education system. Furthermore, by elucidating and adding to the existing literature, it is therefore expected that the present research proposal will expand on our understanding of blended learning.

This dissertation examines the potential benefits and the efficacy of blended learning and as well as, many aspects of the aforementioned relationship. The overarching objective is to obtain a better understanding of the relationship, which has thus far, yielded mixed findings. The dissertation studies will contribute to expanding our understanding of how blended learning, can promote retention and better learning outcomes in different educational settings such as the CEGEP education system. Furthermore, by elucidating and adding to the existing literature, it is therefore expected that the findings of this dissertation will expand on our understanding of blended learning. The remainder of this dissertation is organized as follows.

Chapter 1: This chapter provides an overview of the existing empirical research, including definitions, theoretical frameworks, design models, and effectiveness of blended learning with the primary purpose of identifying critical findings, affordances, and the transformative potentials of blended contexts while addressing the proposed research question: What is the link between blended learning and academic performance? **Chapter 2:** Research has suggested blended learning—which combines FTF classroom instruction with online-mediated instruction without reducing FTF meetings or class time—can enhance both the quality of instruction and student learning outcomes in STEM education. However, little is known about how such instructional approaches affect learning outcomes in the context of CEGEP pre-university science students. Study 1 focuses on a college Mechanics physics course that uses a low-intensity blended learning context with the incorporation of the flipped classroom learning approach and compares the effects of the two learning modes (blended versus traditional) on student academic performance. **Chapter 3:** The last decade has seen an increase in the use of blended learning to support student learning and enhance engagement in STEM education; however, the effect of blended learning on teaching and learning remains unclear and often mixed. This manuscript reports on two studies. The studies draw on data from pre-university science students in the following two courses: (a) Electricity and Magnetism and (b) Waves, Optics & Modern Physics—to examine the relationship between blended learning and academic performance. The proposed studies in this dissertation will attempt to provide deeper insights and contribute to expanding our knowledge and understanding of the association between blended learning contexts and academic performance, particularly, in CEGEP STEM students. An understanding of the topic is vital for both administrators and educators, more importantly, in terms of design approaches and implementations and how these elements of blended learning might be critical to student's academic performance and appreciation. Correspondingly, augmenting our understanding of the topic has relevance for educators, administrators, and researchers—who may have considerable interests over design approaches and, as well as how to incorporate more effective blended learning approaches and best practices. Accordingly, this dissertation will provide an insightful discussion of the results and implications, address some of the essential limitations of and future directions, including outstanding issues in the dissertation.

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Chapter 1

Investigating Blended Learning and its theoretical Framework in Higher Education

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Abstract

This paper investigates the impact of blended learning—which combines face-to-face (FTF) classroom instruction and online-mediated instruction with reduced seat time—in the context of higher education. Although blended learning is a relatively recent addition to the educational landscape, studies have suggested that blended learning can create a more positive and active learning environment and enhance both the quality of instruction and academic performance. Consequently, blended learning has emerged as the "traditional model" and as an area of practice and research, and more likely to become the prevailing paradigm of the future. More importantly, both the effectiveness and learning outcomes of blended learning are well-documented in the literature, and likely to emerge as far more pervasive than either fully online or traditional FTF conditions (Drysdale et al., 2013; Dziuban et al., 2018; Halverson et al., 2012, 2014). Despite the ubiquity of blended learning, there is a lack of single accepted definition or theoretical framework. Importantly, very little research has tried to compare and identify the benefits or shortcomings of blended learning to student achievement. The present review sought to address this gap by examining blended learning contexts from its various of definitions, methodologies, effectiveness, and conceptual framework in higher education.

Keyword: Blended Learning, FTF Classroom & Online-Mediated Instruction, Active Learning, Academic Performance, Learning Outcomes, Achievement

Understand the Definitions and Theoretical Frameworks of Blended Learning

As information and communication technologies (ICT) has become ubiquitous in education, the need for new pedagogical approaches to improve education through the use of technology has been recognized in the educational literature (Englund, Olofsson, & Price, 2016). In response to this, many new pedagogical innovations have been researched and offered. One notable offering is the blended learning (BL) approach, which has received growing interest and attention from the education community (Bernard, Borokhovski, Schmid, Tamim, & Abrami, 2014; Boelens, Voet, & De Wever, 2018; Liu et al., 2016; Means, Toyama, Murphy, & Baki, 2013; Spanjers et al., 2015). Indeed, educators have increasingly turned to the use of blended learning, and new developments in the implementation and use of blended learning continue to be documented (Halverson et al., 2014; Vo, Zhu, & Diep, 2017). Consequently, multiple definitions of blended learning are on offer in the literature (Cuesta-Medina, 2018; Dziuban, Graham, Moskal, Norberg, & Sicilia, 2018; Spring & Graham, 2017).

However, the definitions continue to be contested due in part to the use of blended learning as an umbrella term for different learning approaches and because of the inconsistencies around the “amount of seat time, the proportion of online learning to FTF instruction, and the quality of the educational experience” (Spring & Graham, 2017, p. 338). The terms "blended," "hybrid," "technology-mediated instruction," "web-enhanced instruction," and "mixed-mode instruction" are often used interchangeably for blended learning in the current literature. The definition of blended learning has evolved over the last decade, and only definitions from 2006 to present should be considered topical (Friesen 2012). For instance, a general-purpose definition proposed by Halverson et al. (2014), conceptualizes blended learning as an approach which “combines FTF and online learning modalities” (p. 20).

Friesen (2012) describes blended learning as the system that “designates the range of possibilities presented by combining Internet and digital media with established classroom forms that require the physical co-presence of teacher and students” (p. 1). Staker and Horn (2012) define blended learning as: “a formal education program in which a student learns at least in part through redelivery of content and instruction via digital and online media with some element of student control over time, place, path, or pace" (p. 3).

Most definitions of blended learning commonly conceptualize it as: (a) the use of two or more distinct methods of instructions which combine FTF instruction with technology-mediated instruction (Graham, 2006, 2009); (b) the thoughtful fusion of FTF and online learning experiences (Garrison & Vaughan, 2008); (c) or the combination of FTF and online learning activities (Dziuban et al., 2004). Driscoll and Carliner (2005) describe blended learning as a combination of any form of instructional technology with FTF instructor-led conditions, or a combination of instructional technology with FTF instruction to form a compelling mix of teaching and learning. Bernard et al. (2014) define blended learning as an approach that is composed of a "mix of CI (i.e., face-to-face) and out-of-class OL where the online work substituted for class time” (p. 91).

Essentially the blended learning approach is based on the underlying idea that the "gradual shift from the traditional instruction models towards student-centered ones promotes understanding above pure memorization of the educational content, knowledge retention and positive relationship with the teacher during the carefully created synchronous and asynchronous learning events" (Vasileva-Stojanovska et al., 2015, p. 127). Despite the scant differences between these definitions, more specifically, blended learning is the result of the combination of online-mediated and FTF classroom instruction with reduced seat time.

Although blended learning can encompass a combination of any methods of instructional technologies and pedagogical approaches, the most common definitions of blended learning conceptualize it as the combination of FTF and online (synchronous or asynchronous) instruction. According to more recent studies of online learning by the Sloan Consortium (now called the Online Learning Consortium), blended learning is defined as courses that combine online delivery of content and instruction and FTF instruction with reduced number of FTF meetings, where 30% to 79% of the content is delivered online (Allen et al., 2016). For this review, only the definitions proposed by Allen et al. (2016) and Staker and Horn (2012) will be considered, that is, blended is the combination of FTF and online delivery of content and instruction with some degree of student control over time, place, path, or pace, and where at least 30% to 79% of the content is delivered online. The purpose for considering these two definitions provides a clear distinction between online and FTF conditions, as well as some elements to student control over the learning process and the amount of reduced FTF meetings or seat time.

Research has documented many potential affordances of blended learning, including but not limited to flexibility in terms of place and time (Boelens et al., 2018); some degree of control over their own learning (Spanjers et al., 2015); increased attendance and satisfaction (Stockwell et al., 2015); improving attitudes towards subject matter (Lin, Tseng, & Chiang, 2016), engagement with content (McLean, 2018), and customizable experience (Cuesta-Medina, 2018). Importantly, several studies have considered and illustrated the influence of blended learning on student learning outcomes (López-Pérez, Pérez-López, & Rodríguez-Ariza, 2011). Although blended learning has become a diverse and emergent area of design and inquiry in the educational landscape, the most recent trends or research on blended learning suggest that it lacks a center point or a consistent theoretical framework (Halverson et al., 2014). Consider this, all these theories (e.g., constructivism, community of inquiry (CoI) (Garrison et al., 2000), and self-regulation) have been linked to the blended learning context in some form or another. Accordingly, the lack of a well-established definition or theoretical framework of blended learning (Alammary et al., 2014; Deperlioglu & Kose, 2013; Graham, 2013; Lee et al., 2013) impacts the degree and scope to which educators understand, and design blended courses.

While a myriad of research studies has documented and addressed several blended learning design approaches (Garrison & Vaughan, 2008; Hoic-Bozic, Mornar, & Boticki, 2009; McCarthy, 2010; Newcombe, 2011), relatively fewer research has tried to compare and identify their benefits or shortcomings to learning outcomes, achievement (Alammary et al., 2014; Graham, 2009, 2012), and/or a coherent theoretical framework (Halverson, Graham, Spring, Drysdale, Henrie, 2014). Thus, investigations that address the benefits and shortcomings of blended learning concerning academic performance are both timely and deserving of attention. The comprehensive examination sought to examine blended learning contexts from its various of definitions, methodology, effectiveness, and theoretical framework.

1.1 Systematic Literature Review Method

Using relevant databases and search engines to locate appropriate resources and studies concerning blended learning. Databases such as ScienceDirect, JSTOR, PsycINFO, ProQuest, ERIC, and Google Scholar were used to investigate published articles and studies, including the most impactful or cited articles of blended learning. More importantly, an extensive literature review was conducted to locate articles and studies on blended learning in higher education, including secondary education. To assure that relevant literature was captured in this systematic review, the search process was guided and limited by the research questions. The underlying focus of this review methodologies encompasses the procedure for identifying, classifying, and gathering articles to be included in this systematic review. The scope of the review involves searching for studies relating to blended learning using keywords, idioms, relative terms, and subject headings. Consequently, to accurately locate and identify relevant published articles and studies for the current review, we adopted the inclusion criteria and guidelines for planning, conducting, coding, analyzing, and reporting suggested by Halverson et al. (2012, 2014) for conducting a systematic and thematic review of the literature.

The inclusion criteria were limited to empirical studies in peer-reviewed journals, books, and reports published from 2000 to 2019. The search focused on relevant keywords, research questions, and research designs, more importantly, on empirical studies and theoretical-based findings to conduct this systematic review. Nonetheless, only peer-reviewed articles and reports from 2000 to 2019 were explicitly selected to construct a thematic review for the various definitions and theoretical frameworks of blended learning. However, for a more precise definition of the term blended learning, only peer-reviewed articles from 2004 to present were considered because most definitions before 2004 entail other forms of learning contexts such as the combination between the traditional FTF instructions with any forms of technology-based conditions. According to Friesen (2012), only definitions from 2006 to present should be considered topical. In this review, we commence with the comprehensive description and methods used in Halverson et al. (2012) to congregate and identify studies on blended learning. We then discuss the methods and present the results.

Consequently, this systematic review sought to examine blended learning contexts from its various of definitions, methodology, effectiveness, and theoretical frameworks. Thus, the literature review will be investigated using the following research questions:

1. What are the definitions and theoretical frameworks of blended learning?
2. What are the methodologies that have been adopted for examining the effectiveness of blended learning?
3. How does the design of blended learning affect its implementations?

The search for relevant studies included keywords or relative terms such as “blended or hybrid”, “technology-mediated”, “computer-assisted, “web-based”, “online”, “ flipped”, etc.; ”learning”, “instruction”, “pedagogical approaches”, “training, classroom”, etc; and “education”, “college”, “universities”, “post-secondary”, “undergraduate”, “graduate”, “secondary education”, including secondary searches for constructivism, community of inquiry, and self-regulation. Search terms were derived from the focus of blended learning and academic performance or achievement, using the Boolean operators "AND" and "OR." The search was then categorized by selecting only those studies which (a) specifically focused on blended, hybrid, and technology-mediated learning in education, (b) peer-reviewed, (c) empirical studies, (d) covered definitions, conceptual frameworks, and trends and directions of blended learning. Articles were discarded according to the search criteria proposed by Vo et al. (2017) in their meta-analysis, for example, if the studies: (a) were not conducted in secondary or higher education, (b) did not combine online and FTF conditions for the entire course, (c) did not contrast between blended learning and FTF or fully online conditions, (d) did not measure academic performance based on objective measures such as tests, exams, final marks, overall course grades, GPAs, etc., (e) did not measure subjective measures such as student’s engagement, interaction, satisfaction, etc., and (f) only employed one-group pre–post-test designs. Considerable efforts were made to ensure that all relevant peer-reviewed articles were selected for this systematic review, excluding duplicate, non-peer-reviewed, and conference papers. Consequently, the search for "blended learning" resulted in 401,000 hits, whereas "hybrid learning environments" resulted in 17,700 hits. Only 150 peer-reviewed studies were selected and analyzed for this review based on their outright impacts and number of citations, including seven meta-analyses. The articles were categorized in terms of blended learning definitions, methodology, effectiveness, and theoretical frameworks. In addition, the articles were grouped according to the methodologies used, and a general coding procedure was followed to extract information—relevant to understanding the research question—from this anthology of 150 peer-reviewed studies. Finally, the concluding articles were read, and a table matrix (see Table 4 on page 78) was constructed to record and summarize the relevant information from each peer-reviewed study, which served as the primary unit of analysis.

Furthermore, the articles were coded in Table 4 to examine blended learning effectiveness in terms of research design, study context, analysis techniques, study findings, and general observations. Table 4 summarizes the methodologies adopted for examining the effectiveness of blended learning, including the focus of the studies and the research methodologies (e.g., comparative, quantitative, qualitative, and mixed methods) and findings. The coding and synthesis results are presented in Table 4 and various subsections below, highlighting some key trends and insights drawn from the reviewed studies.

The extant literature attempts to investigate the most current definitions and theoretical frameworks of blended learning contexts. It bears mentioning that these definitions continue to be contested, mainly, because blended learning is a flexible term which can be applied to different learning approaches and may have diverse applications in different contexts (Spring & Graham, 2017). The introduction section of this paper focuses on, the various definitions and terminologies relating to blended learning, including its diverse applications and design aspects, more importantly, its growing popularity and transformative potential in higher education. This review also addresses many potential affordances of blended learning, such as, accessibility and flexibility in terms of place and time, (Boelens et al., 2018), path or pace (Staker & Horn, 2012), as well as increased attitudes (Lin, Tseng, & Chiang, 2016), satisfaction (Stockwell et al., 2015), engagement (McLean, 2018), and learning outcomes (López-Pérez et al., 2011).

The following section focuses on the conceptual frameworks of blended learning, namely, constructivism, community of inquiry (CoI), and self-regulation. This paper, then discusses how these proposed theories or conceptual frameworks could be employed to better investigate and understand the concept of blended learning in higher education. More importantly, to understand how these educational psychology theories are employed to study the student's level of engagement, interaction, and "autonomy" in the online environment. The subsequent sections explore the literature review of blended learning, including the effectiveness and various design approaches of blended learning.

Blended learning design and implementation may be context-, discipline-, or institution-dependent (Lim & Wang, 2017); however, it may be necessary to conceptualize different blended learning models in terms of a single accepted definition and conceptual framework in order to bring about tangible transformations or paradigm shifts in the educational landscape. A review of the literature reveals that blended learning falls under the umbrella of three main design models, that is, low-, medium-, and high-intensity blend, ranging from adding extra online activities to an existing course or full course redesign. In the context of K-12 online education, Staker and Horn (2012) identified four critical models of blended learning: (a) rotation, (b) flex, (c) self-blend, and (d) enriched-virtual. While many of the benefits of blended learning are well documented, however, its adoption and utility can pose enormous challenges for educators, especially in terms of constructions and designs, implementations, sustainability, and scalability. The concept of blended learning may be ingenious in principle; however, it is sophisticated in practice (Lim & Wang, 2017; Wang, Han, & Yang, 2015). The efficacy of blended learning depends significantly on the milieu or context in which it is embraced or in the manner in which it is implemented (Garrison & Kanuka, 2004). Consequently, this paper concludes with a discussion by highlighting some advantages and criticisms for both theoretical and methodological aspect of blended learning, including its utility and effectiveness. Finally, I propose potential research questions for my Ph.D. dissertation concerning design and conduct research in a blended learning environment in higher education.

Theoretical Framework of Blended Learning

A review of the extant literature reveals that there are several theoretical frameworks associated with distance education or blended learning, namely: Community of Inquiry (Garrison, Anderson, & Archer, 2000, 2001), Transactional Distance Theory (Moore, 1993), Communities of Practice (Wenger, McDermott, & Snyder, 2002), Transformational learning theory (Mezirow, 1997), Constructivism (Piaget, 1976; Vygotsky, 1978), and Self-regulation (Zimmerman, 2000, 2002). While there is no single accepted or coherent definition or theoretical framework driving blended learning, however, the existing literature reveals that there are mainly three core theoretical frameworks girding blended learning, namely: constructivism (Driscoll, 2002; Friesen, 2012; Hoic-Bozic, Mornar, & Boticki, 2009; Lim & Wang, 2017; Swan et al., 2010), community of inquiry (CoI) (Drysdale et al., 2013; Garrison, Anderson, & Archer, 2000, 2001; Garrison & Vaughan, 2008; Graham, 2013; Halverson et al., 2012, 2014; Lim &Wang, 2017) and self-regulation (Barnard et al., 2009; Lynch & Dembo, 2004; Shea & Bidjerano, 2009; Schmid et al., 2014; Wu et al., 2010; Zimmerman, 2008). Likewise, this review will focus on these three core theoretical frameworks.

1.2 Constructivism

The prevalence of constructivism in education has brought unfathomable changes to the classroom (Slavin, 1994). “Constructivism” as it was originated by Piaget (1896 - 1980) and Vygotsky (1896 - 1934), emphasizes that learning is an active process, which involves building new knowledge onto prior knowledge. Under constructivism, learners are viewed as producers of knowledge rather than recipients of information (Hadwin & Oshige, 2011). Central to the constructivist view of learning is that teachers cannot merely transfer knowledge into the student's mind; rather, learners must be engaged in constructing their knowledge and understanding. Accordingly, the learner must be held responsible for their learning and education. Constructivism emphasizes that learning is an active, schematic, social, cultural, and effortful process (Mayer, 1996), in fact, the underlying tenet is that the learner must perform mental operations with the information in order to construct new knowledge or meaning (Brooks & Brooks, 1993; Brown et al., 1989; Leinhardt, 1992). Very often, learning is enhanced when learners create mental models on their own or in interaction with peers. Consequently, learning environments such as those incorporating collaboration and active-based learning, and the facilitation of group interactions enable learning through the development of shared understanding of course topics (Dewey, 1938; Hmelo-Silver & DeSimone, 2013; Ramsden, 2003; Richardson, 2003).

Vygotsky’s constructivism emphasized what he saw as the essential role of social influences or interaction in learning and the expansion of knowledge, as he firmly believed that the community and culture play a crucial role in the process of teaching and learning. Vygotsky posited that cognitive development differs across cultures, as cognitive development emerges from social interaction from guided explorations or scaffolding within the "zone of proximal development"[1] as learners co-construct shared understanding or knowledge. The environment in which learners interact influences what they consider or think about and how they co-construct meaning or understanding. Vygotsky believed that social learning guides development.

In contrast, Piaget posited that cognitive development is invariant mainly across cultures. He believed that cognitive development arises primarily from self-directed explorations in which learners are actively engaged in constructing their knowledge. In his view, it was the learners' cognitive development which guides learning. Both Piaget and Vygotsky believed that learners are actively engaged in the learning process. Today, constructivist perspectives on learning have been translated into instructional approaches where students are given more responsibility for their education and the subsequent discovery and development of critical thinking skills and new understandings. If students learn best when they are active participants in their learning, constructivist-inspired instruction seeks to make students mentally involved and engaged in the learning process.

The blended learning approach is undergirded by the constructivist view that learners ought to be actively involved in their learning. The teacher can support and promote this process by effectively using student-centered approaches that make learning more meaningful and more relevant to real-world situations and problems. Student-centered approaches provide students with opportunities to solve problems in real-life, authentic situations, by actively engaging

[1] Skills too difficult for a learner to master on his/her own but can be achieved with guidance and encouragement from a knowledgeable person.

students in the learning process, and by teaching students to be cognizant of their mental schemas and strategies for learning (Slavin, 1994). Blended learning can be characterized as student-centered approach that support more effective collaboration, interaction, co-regulation, and pedagogy (Järvelä & Hadwin, 2013), and has the potential of cultivating more meaningful and lasting learning experiences, particularly, in the online learning community of inquiry. Collaborative learning is central to the co-construction of a shared understanding (Järvelä & Hadwin, 2013; Richardson, 2003) and effective social interactions can be encouraged through the strategic use of technology (Järvelä & Hadwin, 2013; Koschmann, 1996). Consequently, constructivist perspectives such as collaborative and interactive learning strategies embedded in blended learning approaches can foster a greater sense of autonomy, self-directed, and self-regulated learning strategies and behaviors; and thereby promote better learning experiences and outcomes (Graham, 2009, 2012; Means et al., 2013; Vaughan, 2014).

1.3 The Community of Inquiry Framework

The community of inquiry (CoI) framework stems from the collaborative, constructivist approach, and the term is coined as e-constructivism. Garrison, Anderson, and Archer (2000) first proposed the community of inquiry (CoI) model, a theoretical framework of online learning, "the core of which is a collaborative, constructivist view" (Swan, Garrison, & Richardson, 2010, p. 4). A view that is deeply-rooted in Dewey's pedagogical philosophy and practice, the pedagogical experience is engrained in inquiry and community (Dewey, 1959). More specifically, he believes that the educational experience must coalesce the inquisitiveness of the learner and society, and that personal development and growth are contingent upon the community. Dewey posits that the tenet of community involves the spontaneous synthesis of both public and private worlds. For Dewey, the process of inquiry is central to the educational experience; more importantly, he believes that the educational experience is inherently a social activity – that is learning is collaborative and active. Moreover, he believes that through mutual interaction and collaboration the learner would assume a greater sense of culpability to construct knowledge and meaningful learning experiences actively. However, it is this collaborative, constructivist perspective noteworthy of further investigation and research of online learning.

According to Garrison, Anderson, and Archer (2000), CoI is a "conceptual framework that identifies the elements that are crucial prerequisites for a successful higher education experience" (p. 1). A review of the literature reveals that effective online learning, particularly, the element of critical thinking or higher-order learning, require the presence of the community. Swan, Garrison, and Richardson (2010) argue that "the CoI framework is a process model of online learning which views the online educational experience as arising from the interaction of three presences– social, cognitive, and teacher presence" (p.1, see Figure 1).

Figure 1

CoI Framework (Garrison, Anderson, & Archer, 2000, p. 2)

Table 1 summarizes the relationships among the three core elements in the CoI model, including the indicators of those elements and their perspective categories into which these indicators are grouped for a genuine community of inquiry or online learning environment (Arbaugh & Hwang, 2006; Garrison & Arbaugh, 2007; Swan, Garrison, & Richardson, 2010). These co-presences should not be categorized as disconnected, isolated, or distinct parts (Garrison, Anderson, & Archer, 2001; Shea & Bidjerano, 2009). Instead, they are viewed as "multidimensional and interdependent" (Swan, Garrison, & Richardson, 2010, p. 5), and tend to co-exist on a continuum. The CoI framework was developed to study how these crucial elements of the higher education experience can be sustained when the learning environment shifts from the traditional face-to-face approach to the online environment. The CoI model is a conceptual framework, more specifically, a tool that can be used to examine the efficacy and utility of online learning environment while supporting meaningful educational experience (Garrison, Anderson, & Archer, 2000; Swan, Garrison, & Richardson, 2010).

Table 1

Community of Inquiry Elements, Categories, & Indicators (Garrison 2007, p. 159)

Elements	Categories	Indicators
Cognitive Presence	**Triggering Event**	**Sense of puzzlement**
	Exploration	Information exchange
	Integration	Connecting ideas
	Resolution	Apply new ideas
Social presence	**Effective Expression**	**Emoticons**
	Open Communication	Risk-free expression
	Group Cohesion	Encouraging collaboration
Teacher presence	**Design & Organization**	**Setting Curriculum & Methods**
	Facilitating Discourse	Sharing personal meaning
	Direct Instruction	Focusing discussion

The "educational experience is embedded within a community of inquiry that is composed of teachers and students - the key participants in the educational process" (Garrison, Anderson, & Archer, 2000, p. 3). They argue that learning results within the community through the interaction of three core elements, for example, cognitive presence, social presence, and teaching presence. One of the essential elements to success in the CoI model is the cognitive presence. It is "the extent to which the participants in any particular configuration of a community of inquiry are able to construct meaning through sustained communication" (Garrison, Anderson, & Archer, 2000, p. 4). Furthermore, Swan, Garrison, and Richardson (2010) define cognitive presence "as the extent to which learners are able to construct and confirm meaning through sustained reflection and discourse" (p. 8). Not only is Cognitive presence an essential element in the CoI model, but also it is a process that supports and augments critical thinking skills and meaningful learning experience in higher education.

The second element of the CoI model, social presence, "is defined as the ability of participants in the community of inquiry to project their personal characteristics into the community, thereby presenting themselves to the other participants as real people" (Garrison, Anderson, & Archer, 2000, p. 4). Swan, Garrison, and Richardson (2010) argue that "social presence, the degree to which participants in computer-mediated communication feel affectively connected one to another" (p. 9). Furthermore, Garrison (2007) defines social presence "as the ability to project one's self and establish personal and purposeful relationships" (p. 63). Central to cognitive presence is the social presence, that is, social presence precedes cognitive presence and indirectly enhances the process of critical thinking undertaken by a community of learners (Garrison, Anderson, & Archer, 2000). It is argued that the participants in the CoI model must find the interaction or group cohesiveness gratifying and fulfilling for the community to remain sustainable. As a result, social presence leads to superior results and increased educational experience. Dewey posits that effective learning results from experience that is contextually grounded and socially situated (Swan, Garrison, & Richardson, 2010). According to Lipman (2003), "the reflective model is thoroughly social and communal" (p. 25). Thus, social presence is perceived to directly impact the evolution and cohesiveness of the community and collaboration in online courses. For instance, cohesion and collaboration are essential elements directly associated with perceived learning outcomes and meaningful educational experience. It is argued that the tenet of the social presence in a CoI framework is to foster interpersonal connections and purposeful relationships (Swan, Garrisson, & Richardson, 2010).

The third element of the CoI model, teaching presence is defined as "the design, facilitation, and direction of cognitive and social processes for the purpose of realizing personally meaningful and educationally worthwhile learning outcomes" (Garrison & Arbaugh, 2007, p. 163). The importance of teaching presence relating to successful online learning is well documented in a growing body of research (Garrison, Anderson, & Archer 2001, 2010; Garrison, 2009; Swan, Garrison, & Richardson, 2010; Garrison & Cleveland-Innes, 2005). The importance of teaching presence is evident; it is considered “as a significant determinant of student satisfaction, perceived learning, and sense of community” (Garrison & Arbaugh, 2007, p. 163). In fact, teaching presence is the foundation for successful online learning (Garrison, 2007; Garrison & Arbaugh, 2007; Kilis &Yildirim, 2018; Swan et al., 2010). Furthermore, it is argued that the frequency and type of facilitator postings increase students' interaction in an online community of inquiry (Garrison, 2007; Garrison & Arbaugh, 2007).

Teaching presence consists of three elements: (a) Design and organization, (b) Facilitation, and (c) Direct instruction (Anderson, Liam, Garrison & Archer, 2001; Garrison, 2009). According to Garrison, Anderson, and Archer (2000) teaching presence is posited to serve “as a means to an end - to support and enhance social and cognitive presence for the purpose of realizing educational outcomes” (p. 5). The first element of teaching presence focuses on the design and organizational aspect and it "includes the selection, organization, and primary presentation of course content as well as the design and development of learning activities and assessment" (Garrison, Anderson, & Archer, 2000, p. 5). This involves developing, creating, and sustaining a community of inquiry and a collaborative educational experience (Garrison, Anderson, & Archer, 2000, 2010). While the design element in an online learning environment can set both the stage and the promise of the educational experience; yet, designing an effective online learning community of inquiry remains a persistent challenge in higher education. The efficacy of the educational experience in these environments relies solely on the competency of the teaching presence. According to Garrison (2009), "designing an online learning experience is a challenging task as it must concurrently consider social and cognitive presence concerns" (p. 354).

The second element of teaching presence is that the role of the teacher shifts from imparting knowledge (lecturer) to being a mentor, coach, or facilitator in order to promote more effective technology-mediated instruction or collaborative, constructivist learning experiences. A discussion forum is often viewed as a way to promote meaningful discourse and collaborative learning experience in a technology-mediated environment (Garrison, 2009). He argues that collaboration is the outcome of shared experience for the goal of constructing knowledge and confirming meaning. Pointing out that constructing knowledge and meaning-making is a constructivist, collaborative process. In this context, the primary focus of teaching presence is to monitor and facilitate productive, and collaborative engagement and discourse, particularly, in an online learning community of inquiry (Garrison, 2009).

The third element of teaching presence is direct instruction. Shea and Bidjerano (2009) define direction instruction as "the capacity of the instructor to: provide valuable analogies, offer useful illustrations, present helpful examples, conduct supportive demonstrations, and supply clarifying explanations" (p. 552). Swan, Garrison, and Richardson (2010) argue that direct instruction is sometimes necessary for formal educational settings. They describe it as the facility of the teacher to depict clear-cut ideas, diagnose and address misconceptions, encapsulate the discussion, and the ability of the teacher to manage conflict or deliver mini-lecture or lesson. They also argue that these teacher-led approaches can be accomplished openly and collaboratively without having to undercut student-centered approaches for constructing meaning and shared-understanding in an online community of inquiry.

It is argued that teaching presence is required; that is, the teacher will sometimes need to provide guidance and re-direct discussions purposefully (Garrison & Arbaugh, 2007; Garrison, 2009). In some instances, it would be both necessary and crucial for the facilitator to interfere directly to address and clarify misconceptions, provide pertinent information or metacognitive knowledge, and summarize the discussion (Swan, Garrison, & Richardson, 2010). All these practices are crucial to supporting and promoting meaningful engagement in an online collaborative community of inquiry. More importantly, they assert that educators and designers of online learning environment must understand the complexity and scope of teaching presence and its role in the dynamics of a constructivist online learning community of inquiry.

1.4 Self-Regulation in Blended Learning

During the past few decades, new research has sought to better understand how students learn, self-regulate, and control their learning processes, particularly in an online learning environment. Self-regulated learning (SRL) is defined "as the degree to which students are metacognitively, motivationally, and behaviorally active participants in their own learning process" (Zimmerman, 2008, p. 167), or "self-generated thoughts, feelings, and behaviors that are oriented to attaining goals" (Zimmerman 2002, p. 65). Nonetheless, self-regulation is defined as a process in which learners perform various strategies to regulate, monitor, and control their learning (Zimmerman, 2008; Zimmerman & Kitsantas, 2014).

Zimmerman (2008) noted that self-regulation is central to learning effectiveness and performance in any educational context whether it may be face-to-face, online, or blended. He argues that the learner must have personal agency such as personal initiative, perseverance, adaptive skills, and as well as motivational beliefs and metacognitive strategies. Self-regulation is well established in the extant literature, for example, from various theoretical perspectives (Dörnyei & Ryan, 2015), learner beliefs (Zheng, Liang, Yang, & Tsai, 2016), self-efficacy (Lynch & Dembo, 2004; Shea & Bidjerano, 2010; Su et al., 2018), metacognition (Garrison & Akyol, 2015; Kilis & Yildirim, 2018; Snyder & Dringus, 2014), motivation (Kilis & Yildirim, 2018; Zimmerman, 2008), autonomy (Kormos & Csizér, 2014; Snodin, 2013; Zainuddin & Perera, 2019), English language proficiency (Bai, Hu, & Gu, 2014; Su et al., 2018), and academic performance (Kramarski & Gutman, 2006; Kramarski & Mizrachi, 2006). Hence, a review of the extant literature reveals that self-regulation is essential to active learning, and thus the impetus for academic performance (Bergey et al., 2019; Panayiotou et al., 2019; Su et al., 2018; Zimmerman & Schunk, 2011).

As the online learning environment mandates for greater self-efficacy and autonomy, importantly, self-regulation has become the impetus for success in online learning contexts. For example, one essential component of online learning is the autonomy that students experience in the online environment, such as, the flexibility of time, place and path, and the control over when, what, and how to study (Barnard et al., 2009). Researchers posit that self-regulation can help us better understand these distinctive characteristics of online instruction and learning (Azevedo et al., 2004; Barnard et al., 2009; Lynch & Dembo, 2004; Spadafora & Marini, 2018; Zimmerman, 2011). Further review of the literature suggests that learners' differences are directly linked to lack of self-regulation or intrinsic motivation such as self-efficacy (Bergey et al., 2019; Su et al., 2018; Zimmerman 2008, 2011).

Self-efficacy is the belief of one's ability to complete desired tasks and achieve goals or through which insights of one's actions motivate feelings or attitudes about one's ability- which can be achieved through vicarious learning (Bandura, 1997). Research shows that vicarious learning is enhanced through appraisal or by self-comparison (Bergey et al., 2019; Zimmerman, 2002), and learners with higher self-efficacy are more likely to tackle difficult and challenging tasks (Bandura & Schunk, 1981; Su et al., 2018). According to Zimmerman (2002), "if a student fails to understand some aspect of a lesson in class, he or she must possess the self-awareness and strategic knowledge to take corrective action" (p. 65). He argues that learners "who set specific proximal goals for themselves displayed superior achievement and perceptions of personal efficacy" (Zimmerman, 2002, p. 65) regardless of educational contexts. Learners who possess low self-efficacy and who lack intrinsic interest are less likely to tackle more difficult and challenging tasks or take appropriate corrective actions. Zimmerman (2008) posits that SRL is a proactive process that learners must perform to acquire knowledge or skills and, if SRL is central to effective learning then it can be expected to play even a greater significance in understanding online learning environments. Consequently, students lacking in self-regulation may underestimate the "autonomy" of online learning, and thus they may fail to complete the expected online learning lessons or activities in a timely fashion, and thereby affect their academic performance.

As the perspective of students' learning shifts to new context (e.g., online) so must the process of evaluating self-regulation; in fact, learners' self-regulatory processes in traditional classroom settings may disagree from those online learning environments (Barnard et al., 2009; Su et al., 2018; Zheng et al., 2016). Zimmerman (2002) analyzed the construct of self-regulation and identified seven self-directive processes or metacognitive awareness: (a) goal setting, (b) time management, (c) learning strategies, (d) self-evaluation, (e) self-attributions, (f) help-seeking or information, and (g) self-motivation beliefs, such as self-efficacy and intrinsic motivation. Azevedo and his colleagues (2004) measured and assessed learners' self-regulatory processes in hypermedia learning environments through an open-ended think-aloud methodology that enables learners to document their thoughts and cognitive processes while executing a task, and is thus considered as an effective means to measure students' self-regulatory processes online. According to Azevedo and colleagues (2004) learning in online or hypermedia environment entails self-regulatory processes and competencies that learners must navigate, organize, and compile information or knowledge into a practical mental schema or archetypes. These self-regulatory processes consist of goal setting, monitoring, controlling cognition, motivation, and behavior (Zimmerman, 2008). Research shows that student's think-aloud protocols were predictive of superior mental models of a science topic (Azevedo et al., 2004; Zimmerman, 2008), a positive correlation between SRL processes and calibration of knowledge, e.g., academic achievement (Schmitz & Wiese, 2006), and that SRL is not an individual trait that either one possess or lack but something that can be learned or taught (Stoeger & Ziegler, 2007; Zimmerman, 2008). The benefit of self-regulatory behaviors is well documented in the literature, particularly, on students' academic performance (Barnard et al., 2009; Kramarski & Gutman, 2006; Kramarski & Mizrachi, 2006; Su et al., 2018; Zimmerman, 2008, 2011), as well as the importance of learning strategies and self-regulation in learning (Schunk & Greene 2018). In addition, the ability to use self-regulatory processes and use learning strategies effectively are crucial elements of academic skills in higher education (Bol et al., 2016; Kitsantas et al., 2008; Mega et al., 2014).

2. Blended Learning

The proliferation of blended learning is well established in the educational landscape, for example, over 90% of all colleges and universities now offer online learning, and over 6.36 million of students are enrolled in at least one online course, a number that equates to 31.6% of all higher education enrolments in the United States (Allen et al., 2016; Seaman et al., 2018). In particular, more than two-thirds of Canadian higher institutions offer online courses for credit (Bates, 2018). Copious research shows that blended learning is likely to emerge as the prevailing paradigm of the future, and evidently to become far more pervasive than either fully online and the traditional FTF lecture format (Drysdale et al., 2013; Dziuban et al., 2018; Halverson et al., 2012, 2014). In fact, blended learning is rapidly emerging as the "traditional model" or "new normal" (Dziuban et al., 2018; Norberg et al., 2011) in higher education, and as an area of practice and research (Halverson et al., 2012, 2014). This shift is of "sufficient magnitude to be described as an educational transformation or paradigm shift" (Dziuban et al., 2004, p. 1). However, the most recent trends or research on blended learning posits that it lacks a center point or a consistent theoretical framework (Dziuban et al., 2018; Halverson et al., 2012, 2014). Increasingly, blended learning has become far more palpable as an effective teaching and learning instructional strategy than fully online and FTF learning (Means et al., 2013). Furthermore, blended learning is highly regarded and recognized for its transformative potential in higher education (Drysdale et al., 2013; Dziuban et al., 2018; Garrison & Kanuka, 2004; Halverson et al., 2012, 2014).

The widespread acceptance of blended learning has led both educators and institutions to adapt to new pedagogies and technologies, and called on researchers to either reexamine or modify current theories in educational psychology (e.g., constructivism, community of inquiry

(CoI), and self-regulation) in order to better understand and evaluate the level of engagement in online environments. Although the combination of online learning or technology-mediated instruction and FTF classroom instruction known as blended learning is being offered at an increasing number of colleges and universities across North America (Allen et al., 2016; Means et al., 2013; Seaman et al., 2018), recent research on online education reveals that the pervasiveness of K-12 online learning is increasingly gaining widespread acceptance (Bazelais, Doleck, & Lemay, 2018; Docebo, 2017; iNACOL, 2015; Lokey-Vega & Barbour, 2015). Research shows that blended learning contexts coalesced with evidence-based practices enhance students' learning and retention, and the quality of instruction in these courses (Bernard et al., 2014; Ginder & Stearns, 2014; Means et al., 2010, 2013; Tamim et al., 2011).

Blended learning is well established in the constructivist approach— that is learners must be actively involved in their learning. One essential component of the online environment is "autonomy," and this propensity provides some degree of independence or self-determination as students have some control over time, place and path, and/or pace which also imparts to students some degree of responsibility for their learning. Online learning and delivery are meant to replace the typical stand-and-deliver lecture model and homework components of a course, thereby liberating the instructor and the students to focus their energies on more holistic learning experiences (Willis, 2006). Blended learning attracts a diverse range of pedagogies and technologies, which precludes the acceptance of a single, dominant model for designing and developing dynamic and successful blended learning courses. Web-based resources and learning activities embedded in blended learning contexts, e.g., interactive tutorials, podcasts, video lectures, and simulations, can foster student engagement, attention, and autonomy; promote active, self-directed, and self-regulated learning strategies and behaviors; increase time on task; and encourage more in-depth learning experiences (Dziuban et al., 2004; Graham, 2009; Means et al., 2013; Vaughan, 2014).

The application of blended learning instruction or pedagogy is one of the most topical themes in the contemporary literature in higher education (Allen et al., 2016; Means et al., 2010; U.S. Department of Education, 2016). Understanding how blended learning contexts can be used to foster more profound learning experiences is critical for improving instruction and learning. Research shows that technology-mediated instruction such as blended learning is better than the methods used in traditional teaching (Allen et al., 2016, 2017; Bernard et al., 2014; Ginder & Stearns, 2014; Larson & Sung, 2009; Means et al., 2013; Tamim et al., 2011). However, over the past decade most studies have centered mainly on the development of technological tools as complementary to traditional teaching methods, more importantly, support materials for attendance-based pedagogy rather than as a "support for cognition" such as the way intended by proponents of the blended learning contexts (Swoboda & Feiler, 2016; Tamim et al., 2011).

Evidence-based practices (Bernard et al., 2014; Ginder & Stearns, 2014; Means et al., 2010, 2013; Tamim et al., 2011) in online learning suggest that the central features for cultivating student success are to design courses that augment student engagement or time-on-task. Researchers of online education have suggested that both the effectiveness and learning outcomes of blended learning are comparable or superior to the traditional FTF or fully online courses (Allen et al., 2016, 2017; Bernard et al., 2014; Means et al., 2013; Larson & Sung, 2009; Tamim et al., 2011). Blended learning has the potential to improve student access through increased flexibility and convenience as blended courses offer greater flexibility with regards to time, place, and pace, and provide better opportunities to underperforming students and to those who may not have access to FTF instruction. Blended learning hold much promise for underperforming students, as they can increase student engagement by creating a more positive and active environment, which has been shown to enhance both the quality of instruction and student learning outcomes (Means et al., 2010, 2013; López-Pérez, Pérez-López, & Rodríguez-Ariza, 2011).

Although the existing literature has documented many potential affordances of blended learning such as increased flexibility, accessibility, convenience, and satisfaction (Boelens et al., 2018; Spanjers et al., 2015; Stockwell et al., 2015), much of the research has focused, mainly, on the positive influence of blended learning and learner outcomes (López-Pérez, Pérez-López, & Rodríguez-Ariza, 2011). Indeed, the positive influence of blended learning on student learning outcomes has been documented in varied settings: biochemistry (Stockwell et al., 2015), chemistry (Bernard, Broś, & Migdał-Mikuli, 2017); business (Arbaugh et al., 2009), health professions (Liu et al., 2016); computer programming (van Niekerk & Webb, 2016); learning English (Pinto-Llorente, Sánchez-Gómez, García-Peñalvo, & Casillas-Martín, 2017); moral reasoning (Hong, Hwang, Wu, Huang, Lin, & Chen, 2014); gross anatomy (Green & Whitburn, 2016); physics (Hill et al., 2015; Suana et al., 2019) mathematics (Lin et al., 2016), economics (Swoboda & Feiler, 2016), medicine (Ilic et al., 2013, 2015; Makhdoom et al., 2013), among others. A recent meta-analysis conducted by Bernard et al. (2014), for example, found that blended learning conditions exceed classroom instruction conditions by about one-third of a standard deviation ($g^+ = 0.334$, $k = 117$, $p < .001$). Their finding is also similar to other meta-analyses, for example, Means et al. (2013) found that students in blended learning conditions performed better compared to students receiving face-to-face instruction ($g^+ = +0.35$, $p < .0001$). Tamim et al. (2011), found that courses that employed blended learning were significantly more effective (g^+ = +0.33, p = .00, k = 45). Tamim and colleagues (2011) concluded that the effect size (g^+ = .31, p < .01) were significantly higher for technology-mediated instruction as "support for cognition" than those without technology or only using the technology as an add-on, and that technology appeared to have an overall positive effect on teaching and learning (g^+ = +0.35, p < .01). A more recent meta-analysis by Vo et al. (2017) revealed that there was a higher mean effect size in STEM (Science, Technology, Engineering, and Mathematics) disciplines (g^+ = 0.496) compared to non-STEM disciplines (g^+ = 0.210). Furthermore, a meta-analysis conducted by Liu et al., (2016) in the health professions, found that students in blended learning conditions had a larger positive effect than those students in the non-blended learning group (Standardized mean difference = 0.81, 95% CI 0.57-1.05) on knowledge acquisition. Their finding suggests that blended learning is an effective and pedagogically beneficial in health professions, that is, more effective than both traditional FTF and fully online learning. Essentially, blended learning contexts enhance both pedagogy and achievement, particularly in the health professions (Liu et al., 2016) and STEM education (Bernard et al., 2014; Means et al., 2013).

Some research has started to examine the influences of student background and course characteristics on student learning abilities and outcomes. For example, research by Asarta and Schmidt (2017) found differences in performance between blended and traditional learning after considering the influences of prior academic achievement. Studying the proportion of time spent online in a blended course, Owston and York (2018) find that students in the high and medium blends tend to have better perceptions and performance compared to students in the low blends. In examining the predictors of blended learning effectiveness, Kintu, Zhu, and Kagambe (2017) find student characteristics/backgrounds and design features to be significant predictors of student learning outcomes. Van Laer and Elen (2016) review the literature on attributes of blended learning environments that support learners' self-regulatory abilities, finding the following attributes: authenticity, personalization, learner-control, scaffolding, interaction, cues for reflection, and cues for calibration.

Although the vital role of blended learning has been acknowledged in the literature (Bliuc, Goodyear, & Ellis, 2007; Garrison & Kanuka, 2004), much of the thrust in the research has come by means of computer tools as an add-on to traditional teaching methods (Swoboda & Feiler, 2016; Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011). Moreover, implementing blended learning is fraught with challenges (Owston, & York, 2018). Indeed, Boelens, De Wever, and Voet, (2017) review the literature to highlight the following four challenges: "(1) incorporating flexibility, (2) stimulating interaction, (3) facilitating students' learning processes, and (4) fostering an affective learning climate" (p. 1). These challenges (e.g., time spent on investment, increased workload, lack of flexibility and interaction, lack of theoretical framework, etc.) are important and relevant, as researchers have not fully leveraged the blended learning approach. Moreover, Graham, Henrie, and Gibbons (2014) make the argument that there has been limited work on the development and use of theory in blended learning research. In a similar vein, Torrisi-Steele and Drew, (2013) note that there is a paucity of research on the current academic practices in the blended learning literature. Furthermore, to assess the effects of blended learning, Stockwell et al. (2015) point to limited robust assessments of blended learning interventions. Consistent with this observation, Vo et al. (2017) highlight that "there is an imbalance observed in studies on the effect of BL across disciplines, which results in the variation of the BL effect" (p. 17). Moreover, finally, Boelens et al. (2018) note that there is a dearth of information about how instructors use blended learning to deliver personalized instruction for learners; this is important in that the pedagogy ought to be designed and delivered to meet students' needs appropriately and interests (Vanslambrouck, Zhu, Lombaerts, Philipsen, & Tondeur, 2018). In sum, against the discussion above, there is a need to deepen our understanding of the effects of blended learning on student outcomes, as it is critical for improving instruction and learning.

2.1 Blended Learning: Design Models and Implementations

The current literature illustrates three main design approaches to blended learning courses: low -, medium-, and high-intensity blend (see Alammary et al., 2014). In the low-intensity blend, extra online activities are added to a traditional FTF course (for an excellent example of this approach, see López-Pérez, Pérez-López, & Rodríguez-Ariza, 2011; McCarthy, 2010; Cook, Owston, & Garrison, 2004). In the medium-intensity blend, a traditional FTF course is redesigned by replacing some FTF instructions with online instructions and reducing FTF meetings. For an excellent example of this approach, see Garrison and Vaughan (2011), who shifted one hour of a three-hour lecture course per week to online discussions using a Learning Management System (LMS). Finally, in the high-intensity blend, the blended course is designed entirely from scratch. In contrast, Graham (2006) posits that there are three types of blends: (a) enabling blends that increase access, (b) enhancing blends that incrementally improve pedagogy, and (c) transforming blends that create a fundamental shift in paradigm (see Table 2). The three blended learning approaches and definitions suggested by Alammary et al. (2014) and Graham (2006) are comparable to some extent but vary in their emphasis. Thus, these definitions underline that blended learning promotes social interaction, higher-order thinking and problem-solving skills, collaborative learning, formative assessment and feedback, reflection, and, more importantly, how practitioners deliver content (Moskal et al., 2013).

Although many different models or archetypes of blended learning exist, nonetheless, there is no specific best model, or a one size fits all model (Moskal et al., 2013). They argue that the flexibility and affordances of blended contexts grant educators and administrators the facility to personalize the approach or context. These different models tend to strengthen its transformative potential while tackling a new form of pedagogy and addressing the learning needs of a new generation of learners known as "digital natives," learners who “think and process information” in ways that are fundamentally different from previous users (Prensky, 2001). Blended learning, however, has the potential to be more reflective, transformative, accessible and flexible, and as well as, the potential to foster better learning experiences outside the perimeters of traditional classrooms (Jeffrey et al., 2014; Moskal et al., 2013). Research shows that any one of these models can be successful and that there is a weak statistical link between academic success or persistence and delivery modalities (Dziuban & Moskal, 2011; Halverson et al., 2012; Moskal et al., 2013). Consequently, the underlying tenets to a compelling blend can be achieved through continuous effort or by choosing the model that best address the needs of the learner, fits the epistemic belief, philosophy, and vision of both the educator and the institution.

Table 2

Different Categories of Blended Learning Systems (Graham, 2006, p. 31)

Categories	
Enabling blends	Enabling blends to focus on addressing issues of access and convenience. For example, blends that are intended to provide additional flexibility to the learners or blends that attempt to provide the same opportunities or learning experience but through a different modality.
Enhancing blends	Enhancing blends allow for incremental changes to the pedagogy but do not radically change the way teaching and learning occurs. This can occur at both ends of the spectrum. For example, in a traditional FTF learning environment, additional resources and perhaps some supplementary materials may be included online.
Transforming blends	Transforming blends are blends that allow for a radical transformation of the pedagogy. For example, a change from a model where learners are just receivers of information to a model where learners actively construct knowledge through dynamic interactions. These types of blends enable intellectual activity that was not practically possible without technology.

In the low-intensity blend, extra online resources are added to the traditional FTF course structure. According to Kaleta et al. (2007), most teachers designing blended courses add online elements to the traditional course structure without reducing any of the existing activities or seat time. The low-intensity model is called an “add-on” (Tamim et al., 2011) or “the course-and-a-half syndrome” (Kaleta et al., 2007, p. 127). Alammary et al. (2014) argue that in some instances a low-intensity blend may well be appropriate, especially, when first time or inexperienced teachers with low technology competencies create their first blended learning course or in situations where a radical change is not considered necessary. They suggest that most teachers can gain the benefits of blended learning without having to reassess or rethink the entire course objectives within the framework of blended learning. Alammary, Sheard, and Carbone (2014) identified four benefits of the low-intensity blend:

"(1) An easy approach for designing blended learning courses, potentially encouraging hesitant teachers to try blended learning. (2) A quick approach to producing a blended learning course. Driven by a specific pedagogical need, teachers can directly add a new activity that appropriately meets that need without consuming extra time and effort in rethinking and re-planning the whole course or investigating the many possible blended learning components and delivery methods. (3) A low risk of failure when applied carefully…...adding an activity while keeping the traditional course almost the same can minimize these risks. (4) Minimal experience in teaching the traditional course is enough to design the blended course. With limited experience, the instructor can spot the part of the course that could be enhanced by an extra online activity" (Alammary, Sheard, & Carbone, 2014, p. 444).

However, the lack of digital literacy or expertise can pose a challenge for those educators who want to apply this approach successfully; and that, a low-intensity blend has the potential to create two separate courses, for example, one online and one FTF (Alammary et al., 2014; Newcombe, 2011). Consequently, adding extra online activities to a traditional course without reducing seat time often leads to: (a) two separate courses, (b) increase effort and workload for both the instructor and students, and (c) little to no recognition, compensation or incentives for the extra workload and effort (Alammary et al., 2014; Garrison & Vaughan, 2013; Newcombe, 2011).

In other instances, the extra online activities stem from a pedagogical stance (e.g., the flipped-classroom approach) that proves to be a valuable add-on to the traditional course structure. A form of blended learning in which technologies are used to shift direct instruction from the classroom environment to the online environment using technology-mediated instructions (Bergmann & Sams, 2012). A student-centered approach that provides students the opportunity to complete certain activities online or outside of class, while more time is devoted to practice problem-solving skills and concepts in-class under the guidance of the instructor. The Flipped Learning Network (FLN) (2014), define flipped learning as:

"a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter" (p. 1).

They argue that there are four fundamental tenets that can effectively lead to Flipped Learning: (a) teachers must create flexible learning spaces that support students learning needs; (b) teachers must provide students with opportunities to engage in authentic and meaningful tasks without the teacher being central; (c) teachers must create and/ or curate relevant content, promote conceptual understanding and procedural competence, and support student-centered approaches; (d) and teachers must change role from the "sage on the stage" to a guide or a facilitator – to provide relevant feedback and assess students' work.

Second, in the medium-intensity blend, the traditional course outline is restructured by replacing some of the FTF elements with online learning (Alammary et al., 2014; McGee & Reis, 2012; Newcombe, 2011). The underlining concept is that some components of the traditional course would be more effectual as online learning. Whereas the remaining FTF components remain precisely akin, and other cases, significant changes are made to the classroom environment (Alammary et al., 2014).

The existing literature identifies four essential benefits of the medium-intensity approach, for example, (a) enables teachers to start minimally and implement gradually, replacing course activities as required; (b) affords teachers continuing opportunities to experiment with diverse instructional strategies and technological tools to learning while preserving the benefits of the traditional course; (c) allows teachers to gain valuable experience designing this approach which does not intend to significantly transform or make considerable changes to the traditional course structure; and (d) the experience gained in using this approach can help build teachers' confidence in developing and running a blended learning course (Alammary et al., 2014; McGee & Reis, 2012). They argue that there are no well-defined standards to guide decisions as to how or what part of the traditional course should be replaced; and educators must have some excellent technical skills and confidence to apply this approach. More importantly, long-term planning, observation, and evaluation of the course are necessary for the successful implementation of this approach.

Some of the concerns when designing a blended learning course utilizing this approach is to acknowledge which activities or components of the course are most suitable for online learning. However, having little or no prior experience with blended learning or technology-mediated instruction can render this process arduous. Technology is a tool; when used effectively it can improve the quality of instruction and learning experience (Alammary et al., 2014; Aycock et al., 2002); however, technology is less effective unless the teacher feels competence and confidence using that tool (Ertmer et al., 2010; McGee & Reis, 2012).

Lastly, in the high-intensity blend, the blended learning course is designed entirely from scratch. In the current literature, this approach has often been classified as a full redesign, total redesign, radical change. According to Hofmann (2006), educators must first examine every single learning outcome or competencies before considering an entire course redesign approach. They argue that for each outcome, the educator should determine in advance the most suitable delivery modality option (e.g., FTF or online) of that outcome. Furthermore, they suggest that by exploring this approach at the learning outcomes level, educators can create the most efficient blend and, thereby, produce a superior curriculum. This approach is well established in the prevailing paradigm of curriculum development, called constructive alignment, in which assessment tasks are aligned with the learning outcomes (Alammary et al., 2014; Biggs, 1996). Hofmann (2006) argues that it is mistakenly inaccurate to infer that redesigning an existing course will require less time and effort instead of building a new course entirely. The consensus is that educators designing this blended learning approach should build the entire course from scratch, especially, without being burdened of undermining the learning outcomes of the traditional curriculum (Alammary et al., 2014; Hofmann, 2006).

In the case of a high-intensity blend, Alammary et al. (2014) identified three benefits: (a) affords teachers the opportunity to make improvements to while reducing or eliminating potential challenges or issues that the traditional course might embody; (b) allows for better integration of FTF and online components; and (c) offers teachers the opportunity to get the utmost benefits of blended learning while meeting the needs of their students. They argue that building an entire course from scratch affords educators a more significant opportunity to rethink and redesign the entire course according to what learners' need and how they learn best. With this logic in mind, educators can explore and integrate a diverse range of delivery modalities that have been shown to enhance both the quality of instruction and the effectiveness of the course (Alammary et al., 2014). If educators of this approach build their course from a new perspective, in fact, they will have a better chance to create: (a) a more effective blend (e.g., FTF and online), and (b) a more successful course, especially, if the original course has some preliminary issues and challenges (Graham, 2012; Littlejohn & Pegler, 2007). However, there are some key challenges associated with this approach, for example, (a) higher risk of failure because it may lead to new and untested territories, (b) planning and developing a new blended learning course requires more time and effort,(c) designing an effective blend requires experience, (d) higher technological competency and confidence are required to effectively apply this approach, and (e) educators may possibly be overwhelmed with the wide number of potential blended learning components and not understanding fully their implications (Alammary et al., 2014). According to Wozney, Venkatesh, and Abrami (2006), one of the ultimate motivations or impetus for the integration or use of technology in education is, unequivocally, linked to teacher's confidence and level of competency. Consequently, selecting a blended learning design approach requires long-term planning, observation, and evaluation, more importantly, a situated pedagogical framework. Table 3 summarizes the three blended learning design models, in terms of design approaches, benefits, and challenges.

Table 3

Summary of Blended Learning Design Models

Types of Blends	Approach	Benefits	Challenges
Low-intensity	Extra online activities are added to the traditional FTF course without reducing seat time	A quick & easy approach to design a BL course Low risk of failure Flip-classroom approach Active learner classroom	Requires some technological know-how Potential to produce two separate courses (one online & FTF) Increased workload
Medium-intensity	Course is redesigned by replacing some of the FTF instructions with online instructions with reduced seat time	Allows teachers to test different models of BL contexts & pedagogical approaches Allows the teacher to replace course elements as required Builds teacher confidence	Requires good technological knowledge & confidence Takes time and effort Requires long-term planning, observation, and evaluation No defined standards to guide decision-making
High-intensity	Full course redesign or build from scratch	Provides an opportunity to make enhancements Provides superior blends Allows teachers to get the maximum benefit Allows teachers to meet the needs of students better	Requires superior technological expertise Must consider a wide range of blending options Requires experience in designing, developing a new BL course Requires more time Higher risk of failure

2.2 Investigating the Effectiveness of Blended Learning

A review of the literature reveals that most of the empirical studies on the effectiveness of blended learning have been conducted as comparative studies (survey and case studies) contrasting students' academic performance between blended learning and traditional FTF and fully online conditions (Keengwe & Kang, 2012; Means et al., 2013; Vasileva-Stojanovska et al., 2015; Vol et al., 2017). These studies incorporated diverse research methods, such as experimental and quasi-experimental, descriptive and inferential statistics, linear regression, correlational, longitudinal, cross-sectional, as well as different research techniques, such as observations and interviews, self-reporting questionnaires and surveys, content analyses and meta-analyses (Bernard et al., 2014; Keengwe & Kang, 2012; Means et al., 2010, 2013; Vasileva-Stojanovska et al., 2015; Vo et al., 2017). Table 4 summarizes the methodologies adopted for examining the effectiveness of blended learning, including the focus of the studies, and as well as the research methodologies and findings.

According to Vo et al., (2017), the effectiveness of blended learning is studied using objective measures of performance such as quizzes and pre-and post-tests, projects/portfolios, midterm exams, and final test/exam, and as well as affective characteristics measures such as student's engagement, interaction, and satisfaction. Schmid et al. (2014) suggest that researchers should study and analyze pedagogical approaches before they can adequately account for the differences between blended learning and other contexts. More importantly, researchers must also investigate how for example, methods such as end-of-course assessment impact students' learning practices and consequently their academic performance (Struyven et al., 2006; Vo et al., 2017). According to Means et al. (2013), blended learning is more effective than traditional FTF instructions across both recent and older studies, with both younger and older learners, and both in medicine and other subjects, and that undergraduate students seem to benefit the most when using the blended learning approach. Research shows that the impact of blended learning on academic performance is significantly higher for STEM courses compared to non-STEM courses (Bernard et al., 2014; Vo et al., 2017). This finding demonstrates that the implementation of blended learning context is highly encouraged in the STEM field, and thereby prompts instructors of non-STEM discipline to re-evaluate how blended learning is integrated and facilitate more effective learning experiences and discourse, particularly, in the online environment.

Various research studies have concluded that collaborative learning or problem-based learning are effective teaching and learning approaches for engaging students in an online learning community (Keengwe & Kang, 2012; Stockwell et al., 2015; Yeh et al., 2011). They posit that online learning communities contribute to active and collaborative participation, knowledge formation, and as well as increase learning experiences and achievement. Stockwell et al. (2015) conducted a randomized study of blended learning and found that in-class problem solving improves academic performance, and video assignments increase attendance and satisfaction. The impact of blended learning on academic performance has been well documented in diverse contexts, e.g., higher education, secondary education, adult education, and workplace training (Bernard et al., 2014; Means et al., 2013; Schimd et al., 2014; Vo et al., 2017). Although a large body of research show a significant positive effect of blended learning when compared to traditional FTF or fully online conditions (Bernard et al., 2014; Demirer & Sahin, 2013; Larson & Sung, 2009; López-Pérez, Pérez-López, & Rodríguez- Ariza, 2011; Means et al., 2013), but microscopic empirical studies have been conducted on the impact of blended learning on academic performance with regards to disciplines, mainly, as methods of end-of-semester assessment (Vo et al., 2017).

Although blended learning is a new area of research and has become the paradigm of the future, however, this new area of research demands for new or other forms of research methods to examine its effectiveness thoroughly. Consequently, educators and researchers of online learning should consider precisely how theories such as self-regulation and the community of inquiry (e.g., cognitive and social presence) are implemented to evaluate the effectiveness of the online environment. However, there is still a gap on how these co-presences (cognitive and social) in the CoI model, including self-regulation, are utilized to implement more effective blends and designs approach in education, or how they are used by educators to promote better learning experiences and outcomes. While there are increasing interests and demands to investigate and offer hands-on methodologies that practitioners can use to implement blended learning, however, more research is required to investigate the effectiveness of blended learning contexts, particularly, in non-STEM disciplines, and the moderating factors of subject matter, instructional strategies, and self-regulation.

Table 4

Summary of Methodologies Adopted for Examining the Effectiveness of Blended Learning

What are the Methodologies that have been Adopted for Examining the Effectiveness of Blended learning?		
Reference	**Methods**	**Specifics**
Miyazoe, T., & Anderson, T. (2010). Learning outcomes and students' perceptions of online writing: Simultaneous implementation of a forum, blog, and wiki in an EFL blended learning setting. *System*, *38*(2), 185-	Quantitative & Qualitative methods used: interviews questionnaires, & written assignments	Quantitative evaluation: students rated an overall evaluation of the blended course on a five-point scale. Interview questions

199. doi: 10.1016/j.system.2010.03.006		were used to gauge students' perceptions of the blended learning course design. Students' forum and blog posts were analyzed using text analyzer.
Mahnken, A., Baumann, M., Meister, M., Schmitt, V., & Fischer, M. (2011). Blended learning in radiology: Is self-determined learning really more effective?. *European Journal Of Radiology*, *78*(3), 384-387. doi: 10.1016/j.ejrad.2010.12.059	Group comparisons between three groups: e-learning environment was accessed on a self-determined basis (Group 1), mandatory basis (Group 2), and control group (Group 3) without access to the e-learning environment	The pre-& post-course assessment was used to analyze learning outcomes quantitatively. Changes in knowledge were compared across the three groups. Variables recorded: total time on e-cases, mean time per e-case, total number of accessed e-cases, and total number of successfully passed e-cases
Yeh, Y. (2010). Integrating collaborative PBL with blended learning to explore preservice teachers' development of online learning communities. *Teaching And Teacher Education*, *26*(8), 1630-1640. doi: 10.1016/j.tate.2010.06.014	1). Analyze the content of asynchronous discussions; 2). group's learning portfolio was analyzed	Both a qualitative content analysis approach and a quantitative content analysis approach of the online discussions and learning portfolios
Arroyo-Morales, M., Cantarero-Villanueva, I., Fernández-Lao, C., Guirao-Piñeyro, M., Castro-Martín, E., & Díaz-Rodríguez, L. (2012). A blended learning approach to palpation and ultrasound imaging skills through supplementation of traditional classroom teaching with an e-learning package. *Manual Therapy*, *17*(5), 474-478. doi: 10.1016/j.math.2012.04.002	A comparative study between two groups: blended learning with an e-learning package vs. Control group with access to documents and books on the topic.	Differences between the two groups were assessed on the following: Structured objective clinical evaluation (SOCE), multiple-choice questionnaire (MCQ), time taken to produce ultrasound image and to palpate the musculoskeletal structure

Yang, Y., Chuang, Y., Li, L., & Tseng, S. (2013). A blended learning environment for individualized English listening and speaking integrating critical thinking. *Computers & Education, 63*, 285-305. doi: 10.1016/j.compedu.2012.12.012	Pretest-posttest one-group design was used to test the effectiveness of blended learning environment for English listening and speaking instruction	Dependent variable measures included Critical thinking skills, Critical thinking dispositions, and English listening and speaking abilities
Stockwell, B. R., Stockwell, M. S., Cennamo, M., & Jiang, E. (2015). Blended Learning Improves Science Education. *Cell, 162*(5), 933-936. doi:10.1016/j.cell.2015.08.009	Randomized control trial: two-by-two study design, comparing the effects of both video vs. textbook pre-class assignments & lecturing with instructor-led problems vs. lecturing with student problem-solving in class	Measured impact on exam score and attendance. In-class problem solving improved exam performance, while video assignments improved attendance and satisfaction.
Sung, Y. H., Kwon, I. G., & Ryu, E. (2008). Blended learning on medication administration for new nurses: Integration of e-learning and face-to-face instruction in the classroom. *Nurse Education Today, 28*(8), 943-952. doi:10.1016/j.nedt.2008.05.007	blended learning (integrating e-learning elements) vs. face-to-face instruction for nurses in medication administration	dependent variables were compared: degree of knowledge of medication, self-efficacy of medication administration, medication-administration ability, and satisfaction with the learning program.
Glogowska, M., Young, P., Lockyer, L., & Moule, P. (2011). How ‘blended’ is blended learning?: Students perceptions of issues around the integration of online and face-to-face learning in a continuing professional development (CPD) health care context. *Nurse Education Today, 31*(8), 887-891. doi:10.1016/j.nedt.2011.02.003	A Qualitative Study: Students were interviewed to report experiences with blended learning in order to gauge their perceptions of blended learning modules in a continuing professional development health care setting.	Participants' views were used to create a thematic analysis of blended learning
Rigby, L., Wilson, I., Baker, J., Walton, T., Price, O., Dunne, K., & Keeley, P. (2012). The development and evaluation of a ‘blended' inquiry-based learning model for mental health nursing students: "making your experience count."	Three focus groups of students in a blended learning pedagogical model: a perspective of the face-to-face experience compared with the e-learning component.	Data analyzed using a thematic approach.

Nurse Education Today, 32(3), 303-308. doi:10.1016/j.nedt.2011.02.009		
Smyth, S., Houghton, C., Cooney, A., & Casey, D. (2012). Students experiences of blended learning across a range of postgraduate programmes. *Nurse Education Today, 32*(4), 464-468. doi:10.1016/j.nedt.2011.05.014	Students in Nursing and midwifery taking a blended learning postgraduate programs were interviewed in focus groups.	A qualitative interpretive descriptive design was used to gather and analyze data. Specifically, thematic data analysis was used to analyze data.
So, H., & Brush, T. A. (2008). Student perceptions of collaborative learning, social presence, and satisfaction in a blended learning environment: Relationships and critical factors. *Computers & Education, 51*(1), 318-336. doi:10.1016/j.compedu.2007.05.009	Graduate (in health education) students' perceived levels of collaborative learning, social presence and overall satisfaction in a blended learning environment were measured using Collaborative learning, social presence, and satisfaction (CLSS) questionnaire and face-to-face interviews	This was a case study involving a mixed methodology (questionnaire and interview). CLSS data was used to develop student profiles. Interview data (using thematic analysis) was used to identify factors affecting student perceptions of collaborative learning, social presence, and satisfaction.
Wu, J., Tennyson, R. D., & Hsia, T. (2010). A study of student satisfaction in a blended e-learning system environment. *Computers & Education, 55*(1), 155-164. doi:10.1016/j.compedu.2009.12.012	Determinants of students' learning satisfaction in a blended environment. The study applied the social cognitive theory. Quantitative study: application of partial least squares (PLS)	A structural model was tested to determine the antecedents of learning satisfaction. Learning climate and performance expectations significantly affect learning satisfaction.
Kintu, M., Zhu, C., & Kagambe, E. (2017). Blended learning effectiveness: the relationship between student characteristics, design features, and outcomes. *International Journal Of Educational Technology In Higher Education, 14*(1). doi: 10.1186/s41239-017-0043-4	The effectiveness of blended learning assessed through the relationships between student characteristics/background, design features, and learning outcomes. Quantitative study:	Learning outcome: final semester evaluation results. Other surveys: online self-regulatory learning questionnaire for data on learner self-regulation and the intrinsic motivation

		inventory for data on intrinsic motivation
Olitsky, N., & Cosgrove, S. (2014). The effect of blended courses on student learning: Evidence from introductory economics courses. *International Review Of Economics Education*, *15*, 17-31. doi: 10.1016/j.iree.2013.10.009	Comparative analysis of learning outcomes between blended and FTF courses in introductory economics courses.	The study compared the scores on quizzes and exams and found that there were no significant effects of blending on student learning outcomes
Lim, D. H., & Morris, M. L. (2009). Learner and Instructional Factors Influencing Learning Outcomes within a Blended Learning Environment. *Educational Technology & Society*, *12* (4), 282–293.	Quantitative Analysis of the influence of instructional design, learning involvement and learning motivation on student learning outcomes in a blended environment. Qualitative Analysis: open-ended responses were analyzed to identify themes & patterns in the reasons that promote or hinder learners' learning and application during learning.	Three forms of learning outcomes: actual learning; perceived learning; and perceived learning application. Learning motivation: Learning Motivation Questionnaire (LMQ). Learners' satisfaction: quality of the instructor, learning activities and learning support, and the learners' perception of study workload was used. Learning involvement: eight question items asking students' perceived involvement in the areas of interest in subject content, learning progress, learning involvement, personal effort, preparedness, and personal challenge.
Woltering, V., Herrler, A., Spitzer, K., & Spreckelsen, C. (2009). Blended learning positively affects students’ satisfaction and the role of the tutor in the problem-based learning process: results of a mixed-method evaluation. *Advances In Health Sciences Education*, *14*(5),	Comparative analyses of blended problem-based learning (bPBL) & traditional PBL. Qualitative & quantitative questionnaire used.	Qualitative and quantitative questionnaires, standardized group interviews, and students’ test results were used in the study. Furthermore, log-files of the group-wiki were

725-738. doi: 10.1007/s10459-009-9154-6		also analyzed. Students in the bPBL group rated higher in motivation, subjective learning gains, and satisfaction.
Williams, N., Bland, W., & Christie, G. (2008). Improving student achievement and satisfaction by adopting a blended learning approach to inorganic chemistry. *Chem. Educ. Res. Pract., 9*(1), 43-50. doi: 10.1039/b801290n	The examination marks and module results were compared between two modules (one run using a blended learning approach and another delivered as a lecture workshop course) of inorganic chemistry.	An analysis of module results revealed an improvement in performance after introducing blended learning. Moreover, module questionnaires suggested a significant improvement in student satisfaction with subject content, delivery and performance feedback.
Duque, G., Demontiero, O., Whereat, S., Gunawardene, P., Leung, O., & Webster, P. et al. (2012). Evaluation of a blended learning model in geriatric medicine: A successful learning experience for medical students. *Australasian Journal On Ageing, 32*(2), 103-109. doi: 10.1111/j.1741-6612.2012.00620.x	Blended learning approach in geriatric medicine was evaluated through feedback from students.	Students' responded on their learning experience in the blended learning rotation compared to previous rotations. A pre-to-post evaluation design used to assess the effectiveness of each module on students' learning: Results suggested a significant pre- to post-knowledge increase after interaction with each learning module.
Milic, N., Trajkovic, G., Bukumiric, Z., Cirkovic, A., Nikolic, I., & Milin, J. et al. (2016). Improving Education in Medical Statistics: Implementing a Blended Learning Model in the Existing Curriculum. *PLOS ONE, 11*(2), e0148882. doi: 10.1371/journal.pone.0148882	Comparing blended learning to traditional learning approach in medical statistics. Outcome variables were compared between the two groups.	Mean exam scores for the two groups were compared: blended learning student group had higher mean exam score for both the final statistics score and the written knowledge test score.

Sherman, H., Comer, L., Putnam, L., & Freeman, H. (2012). Blended Versus Lecture Learning. *Journal For Nurses In Staff Development*, *28*(4), 186-190. doi: 10.1097/nnd.0b013e31825dfb71	Randomized controlled trial: Comparison of blended vs. traditional lecture for critical care pharmacology education.	Participants completed a written critical care pharmacology test and participated in a focus group (to provide feedback and information). The study measured: demographics, cognitive learning, and educational effectiveness — no significant differences in cognitive learning outcomes or learner satisfaction between blended and traditional lecture.
Kavadella, A., Tsiklakis, K., Vougiouklakis, G., & Lionarakis, A. (2011). Evaluation of a blended learning course for teaching oral radiology to undergraduate dental students. *European Journal Of Dental Education*, *16*(1), e88-e95. doi: 10.1111/j.1600-0579.2011.00680.x	A comparative study between two groups in an undergraduate oral radiology course: blended learning and conventional course (FTF)	Evaluation-satisfaction questionnaire: students' perceptions, expectations, attitudes and skills, communication and satisfaction related to the course design, delivery and outcome. Outcomes: knowledge assessment tests and grades (before and after the course). Blended learning students performed better than the conventional group in the post-course knowledge test.
Cortizo, J., Rodríguez, E., Vijande, R., Sierra, J., & Noriega, A. (2010). Blended learning applied to the study of Mechanical Couplings in engineering. *Computers & Education*, *54*(4), 1006-1019. doi: 10.1016/j.compedu.2009.10.006	A quasi-experimental comparative study between two groups in the subject Machine Technologies: BL (FTF & online) vs. traditional mode (FTF & note taking)	Pretest, followed by 40 min experiment where the two groups consulted the information. Then both groups took the post-test. Evaluation of the results suggested that there was a greater

		increase in learning in the blended learning group.
Alonso, F., Manrique, D., Martinez, L., & Vines, J. (2011). How Blended Learning Reduces Underachievement in Higher Education: An Experience in Teaching Computer Sciences. *IEEE Transactions On Education*, *54*(3), 471-478. doi: 10.1109/te.2010.2083665	Comparative study of different instructional conditions in teaching computer sciences.	Independent Variables: Instructional condition and academic year, with five levels: blended learning taught in one year, distance learning taught in one year, and face-to-face learning taught over three years. Dependent variable: overall course performance, graded from 0 to 10. Students in the blended group received higher grades than students in the traditional group.
Zacharis, N. (2015). A multivariate approach to predicting student outcomes in web-enabled blended learning courses. *The Internet And Higher Education*, *27*, 44-53. doi: 10.1016/j.iheduc.2015.05.002	Quantitative (learning analytics) study used to predict students' final grade from log data from a web-enabled blended learning course (a Moodle Learning Management System) on Java Programming.	Usage variables from the learning management system analyzed. From the 29 usage variables, 14 were significantly correlated to the course grade. These 14 variables were used in a stepwise multivariate regression for prediction of students' final grade. This process found that the four variables (Reading and posting messages, Content creation contribution, Quiz efforts, and Number of files viewed) predicted 52% of the variance in students' final grade.

Broadbent, J. (2017). Comparing online and blended learner's self-regulated learning strategies and academic performance. *The Internet And Higher Education*, *33*, 24-32. doi: 10.1016/j.iheduc.2017.01.004	Comparative study of Self-regulated learning strategies used in Online and Blended learning contexts.	Students in both the online and blended learning groups completed the Motivated Strategies for Learning Questionnaire (MSLQ) used to measure students' self-regulated learning strategies. Students in the online group used SRL strategies more often than blended learning students (with the exception of peer learning and help-seeking). Furthermore, correlation analyses were performed to examine the links between SRL strategies and subject grade.
Melton, B., Bland, H., & Chopak-Foss, J. (2009). Achievement and Satisfaction in Blended Learning versus Traditional General Health Course Designs. *International Journal For The Scholarship Of Teaching And Learning*, *3*(1). doi: 10.20429/ijsotl.2009.030126	To investigate the effectiveness of blended learning in a general health course. A quantitative pre-&post-test control group design. Comparison of students' achievement and satisfaction between blended learning courses and traditional FTF course.	Outcome variable: students' course grades and end-of-course class satisfaction (modified Students' Evaluation of Educational Quality (SEEQ)) and teacher evaluation. Student in the blended sections achieved higher scores in final course grades; however, the difference in pre-posttest scores was not significantly different.
Kwak, D., Menezes, F., & Sherwood, C. (2014). Assessing the Impact of Blended Learning on Student Performance. *Economic Record*, *91*(292), 91-106. doi: 10.1111/1475-4932.12155	Difference-in-differences method to assess the impact of blended learning in a first-year statistics course for business and economics students	Findings suggest that the link between blended learning and students' performance depends on whether the effect of blended

		learning is cumulative or not.
Wakefield, A., Carlisle, C., Hall, A., & Attree, M. (2008). The expectations and experiences of blended learning approaches to patient safety education. *Nurse Education In Practice*, *8*(1), 54-61. doi: 10.1016/j.nepr.2007.04.007	Qualitative study used to examine the efficacy of blended learning in patient safety education.	Data collection: pre and post-course Confidence Logs, Individual Interviews (before and after training), Focus Groups and Evaluation Questionnaires (post course). Content analysis was performed to generate themes.
Deschacht, N., & Goeman, K. (2015). The effect of blended learning on course persistence and performance of adult learners: A difference-in-differences analysis. *Computers & Education*, *87*, 83-89. doi: 10.1016/j.compedu.2015.03.020	Difference-in-difference research design: to test the effect of blended learning on students' academic success (and persistence) in the first year of a business education curriculum.	The treatment effect of blended learning in the group of adult learners, while the regular learners used as a control group. Three dependent variables to measure the course persistence and performance of students: dropout rate; exam pass rate; and overall course pass rate. Blended learning improves exam performance.
Owston, R., York, D., & Murtha, S. (2013). Student perceptions and achievement in a university blended learning strategic initiative. *The Internet And Higher Education*, *18*, 38-46. doi: 10.1016/j.iheduc.2012.12.003	The link between students' perceptions of blended learning and course achievement.	Student perceptions: overall satisfaction with blended learning; convenience provided by blended learning; a sense of engagement in blended learning; and view on learning outcomes. Dependent variable: final course grade. The study found a link between students' perceptions and grades.

Banditvilai, C. (2016). Enhancing Students' Language Skills through Blended Learning. *Electronic Journal of e-Learning*, *14*(3), 220-229.	Examine the effectiveness of a blended learning environment via a comparative study of blended learning and traditional classroom setting in Communicative Business English class	Outcomes: At the end of the semester, both the control group and the experimental group took a post-test (achievement test). An additional questionnaire measured student’s (in the blended group) reactions towards using e-learning. Further, students from the blended group participated in interviews that recorded their opinions on using e-learning.
Kazu, I. Y., & Demirkol, M. (2014). Effect of Blended Learning Environment Model on High School Students' Academic Achievement. *Turkish Online Journal of Educational Technology-TOJET*, *13*(1), 78-87.	Comparison of the blended learning environment and traditional learning environment in first-semester biology course in high school.	Pretest: to evaluate students' knowledge before the study. A final test showed that there was a significant difference between final test scores between the students in the blended and traditional learning groups (with students in the blended learning environment scoring higher than students in the traditional learning group).

2.3 Significance of the Study

This review provides new insights into the incorporation of the blended learning approach in the context of higher education. It demonstrates how adopting different blended learning contexts (e.g., low-, medium-, and high-intensity blends) coupled with different pedagogical approaches can enhance student performance and, consequently, improve the quality of instruction in the college classrooms, particularly, in STEM education. It is suggestive of how comparable blended learning approaches can be used to foster quantifiable change and satisfaction in the college classroom, thereby increasing student performance and retention at both colleges and universities. The strategies employed in a blended learning approach can be used to foster and create a more positive and collaborative learning environment. Finally, it appears that blended learning offers an enjoyable and successful way for students to learn, to improve their skills or mastery of lecture content, and performance, as well as increased effectiveness, convenience, and efficiency.

This literature review is crucial as it attempts to provide a better understanding of the term and concept of blended learning. Most research on blended learning has not been heuristic or empirical but instead has focused mainly on the definitions, methodologies, and the transformative potential of blended learning (Halverson et al., 2012, 2014). The existing literature shows that the most recent streams of blended learning research have focused on comparative studies that examined the potential predictors of course outcomes with FTF and fully online conditions (Arbaugh et al., 2009; Keengwe & Kang, 2012; Vasileva-Stojanovska et al., 2015; Vol et al., 2017). Hitherto, findings on comparison studies suggest that blended learning improved learning outcomes (Bernard et al., 2014; Drysdale et al., 2013; Means et al., 2013; Larson & Sung, 2009; Tamim et al., 2011), however, the understanding of how and why is not entirely conclusive, and thus warrants further research (Graham, 2013). While the review provides some emerging understanding and critical findings of blended learning, however, some new questions emerge and prompt some openings for future research.

Despite these positive effects of blended learning, there is still a gap, for example, the lack of coherence or tested conceptual frameworks, or discipline-specific theories that practitioners can use to develop and design blended learning contexts. Yet, very little research has shown how exactly educational psychology theories (e.g., constructivism, CoI, and self-regulation) can be incorporated into blended learning contexts, more specifically, how these theories can be used to inform design and practice. In this context, blended learning must be grounded in theory, and that future research should study and analyze the iterative association between conceptual framework and practical applications (Drysdale et al., 2013). Future research should also study and analyze how pedagogical approaches impact blended learning effectiveness, more importantly, future research should study and summarize empirical studies relating to blended learning based on the latest trends and definitions of the concept. Third, future research should focus on pedagogy and design, outcome effectiveness, satisfaction, access and convenience, as well as a contemporary conceptual framework that differentiate blended learning contexts from other forms of teaching-learning. Thus, it is imperative that these blended learning methods receive proper attention and are addressed in future research to better understanding and fully realize the transformative potential of blended learning in higher education.

Conclusion

As the need for new pedagogical approaches to improve 21st-century teaching and learning receive increasing interest and attention, blended learning is recognized as one notable solution to this growing crisis. In the current literature, blended learning is recognized as a transformational new area of design and inquiry that can exceed some of the various limitations associated with the traditional FTF or fully online conditions, because it combines the best of both worlds and espouses best practices and benefits of these types of instructions (Keengwe & Kang, 2012). Although the impact of blended learning on academic performance has been well documented in diverse contexts, e.g., higher education, secondary education, adult education, and workplace training (Bernard et al., 2014; Means et al., 2013; Schimd et al., 2014; Vo et al., 2017), and that blended learning is far more effective than traditional FTF or fully online conditions, mainly, in the STEM discipline. However, with the various number of blended learning contexts and designs, selecting the best-blended learning approach can pose an enormous challenge and enigma for both institutions and educators. The lack of a single accepted definition or theoretical framework enables some educators to understand and conceptualize blended learning differently, and thereby, affect how they design and blend their courses (Moskal, Dziuban, & Hartman, 2013).

While blended learning is increasingly popular and perceived as the paradigm of the future, however, new forms of research methods are warranted to examine its effectiveness thoroughly. For example, (a) how can theory inform design approaches and hands-on practices, (b) the role of the instructor, (c) how to accurately measure its effectiveness on academic performance, (d) the need to assess the current state of K-12 blended learning, and (e) more research is required to investigate the effectiveness of blended learning, particularly, in non-

STEM disciplines. Consequently, more research is required to help educators understand better how to maximize the benefits, measure the effectiveness, address the challenges, and develop a conceptual framework to address the specificity and uniqueness of blended learning contexts. This literature review has identified and outlined the many affordances and shortcomings of blended learning, including definitions, methodologies, effectiveness, and conceptual frameworks.

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Bridging Text

In Chapter 1, the systematic review synthesizes empirical-based findings of the current literature, via a comprehensive review and analysis that examines the many positive effects that have been documented to investigate the link between blended learning and academic performance in higher education. The review discovered that the relationships between blended learning and academic performance have often yielded mixed or inconclusive findings, thus calling for further research. Through three empirical studies, this dissertation addresses the gaps in the literature relating to the effectiveness of blended learning and academic performance, particularly, in pre-university students' population. Study 1 investigates the link between blended learning and academic performance—using a low-intensity blended context as a point of reference for the follow-on studies (Studies 2 and 3) in this multi-study dissertation. Specifically, Study 1 sought to empirically assess the effectiveness of instruction and the direct relationship between blended learning and academic performance in the physics Mechanics course in the pre-university program at an English CEGEP, comparing the blended learning approach and the traditional lecture-based instruction.

Chapter 2: Study 1

Blended Learning and Traditional Learning: A Comparative Study of College Mechanics Courses

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Abstract

Research has suggested that blended learning can enhance both the quality of instruction and student learning outcomes in STEM (Science, Technology, Engineering, & Mathematics) education. However, little is known about how such instructional approaches affect learning outcomes in the context of *Collège d'enseignement général et professionnel* (CEGEP) pre-university science students. The present study focused on a college Mechanics course at a CEGEP that used blended learning and compared the effects of the two learning modes (blended versus traditional) on student academic performance. Overall, the study revealed that students in the blended classroom (treatment) experienced more conceptual change and higher performance compared to the students in the traditional lecture-based class (control group). The findings offer support for the push to implement alternative approaches to instruction such as blended learning. Moreover, the study also improves understanding of the effects of blended learning on understudied samples such as CEGEPs.

Keywords: Blended learning, STEM education, pre-university science students, academic outcomes

Introduction

Given the pressing issues plaguing STEM fields—such as declining rates of STEM degree production, lack of interest in STEM fields, lack of preparedness and appropriate support to excel in STEM, gender gap, and lack of diversity (Baber, 2015; Else-Quest, Hyde, & Linn, 2010; Good, Rattan, & Dweck, 2012; Greene, DeStefano, Burgon, & Hall, 2006)—researchers have sought different approaches and strategies to improve instruction, learning, and engagement in STEM courses (Baldwin, 2009; National Research Council, 2011) to remedy deficiencies and meet the mounting STEM challenges. The traditional lecture approach—which continues to be the prevalent means of instruction—has been criticized as an ineffective way to science instruction (Deslauriers, Schelew, & Wieman, 2011; Hake, 1998). Further, effective learning emphasizes and requires the learner to be active in the learning process (Dori & Belcher, 2005; Hake, 1998; Mayer, 1996). As calls for STEM education improvements grow, many have turned to technology to provide potential answers. As technology becomes ubiquitous, the uptake of technology in education has resulted in new forms of instruction. Indeed, research has examined the potential of new forms of instruction, such as blended learning to implement reforms and address some of the shortcomings in traditional instructional methods and settings (Porter, Graham, Spring, & Welch, 2014; VanDerLinden, 2014) as a way to provide improved learning opportunities and experiences to help students to learn complex concepts in STEM. Blended learning can be implemented in many ways, such as the flipped classroom, which can be understood as a learning approach in which technologies are used to shift direct instruction from the classroom to the online environment using interactive online videos (Bergmann & Sams, 2012). Furthermore, the flipped classroom approach provides a means to foster active learning strategies and help students further achieve the necessary mastery by maximizing class time dedicated to problem-solving and deep conceptual understanding (Bergmann & Sams, 2012; Mazur, 2013). As such, there continues to be a need to better understand the impact of such approaches on students' learning outcomes.

Despite the increased interest in promoting new instructional approaches to promote STEM education, there is limited research on the impact of blended learning on CEGEP students (see for a primer on the CEGEP system, Bazelais, Lemay, & Doleck, 2016). In the pre-university science program at the CEGEP (where the present study was conducted), student success in the advanced physics courses is largely tied to their performance in introductory physics courses. For example, students who perform poorly in the introductory mechanics course generally tend to display similar levels of poor performance in in the subsequent Electricity & Magnetism course. To remedy the situation, the blended learning approach was adopted and implemented as a potential means to improve problem-solving and deep conceptual understanding in the introductory mechanics course at the CEGEP. Thus, in the present study, we examine the efficacy of the flipped classroom model of blended learning in a first semester physics course on mechanics. To do so, we compare students' learning outcomes in the two learning scenarios: blended learning vs. traditional instruction. Thus, the following research question guided the present study: Does a flipped classroom model of blended learning result in higher performance on the standardized final exam in a CEGEP mechanics course?

Background: Blended Learning

Blended learning has received considerable interest from scholars and practitioners (Bernard, Borokhovski, Schmid, Tamim & Abrami, 2014; Bliuc, Goodyear, & Ellis, 2007; Garrison & Kanuka, 2004; Kim, Bonk, & Teng, 2009; Lim & Morris, 2009; Vaughan, 2007). According to a survey of US higher education institutions, "almost 55 percent of all institutions offer at least one blended course" (Allen, Seaman, & Garrett, 2007, p. 7). As with any new development, blended learning too comes with many definitions (Bliuc et al., 2007; Watson, 2008).

For this study, blended learning is defined as the combination of traditional FTF methods with online activities (see Cook, Owston, & Garrison, 2004; Garrison & Kanuka, 2004; Graham, 2006; Macdonald, 2008) where the online component is supplementary to the traditional FTF context. This approach to blended learning is referred to as the "supplemental model" (Graham 2013; Graham 2009; Twigg, 2003); or "enhancing blend" (Graham 2006). Furthermore, the concept of blended learning can be considered as (a) any combination of traditional FTF instruction with other resources delivered online (Garrison & Kanuka, 2004; Harrison, 2003; Oliver & Trigwell, 2005); or (b) "courses that integrate online with traditional face-to-face class activities in a planned, pedagogically valuable manner" (Picciano, 2005, p. 97). According to these definitions, there is no standard approach to the proportion of the FFT condition delivered online (Aycock, Garnham, & Kaleta, 2002). In the sense that blended learning should be tackled not simply as a temporal construct but rather as a fundamental redesign of the instructional model, shifting from lecture to student-focused pedagogy, emphasizing active and interactive learning strategies (Dziuban et al., 2004). While such a definition might be seemingly simple, Garrison and Kanuka (2004) note that blended learning can be both simple and complex ("with the challenge of virtually limitless design possibilities") (p. 96). To provide further color to framing blended learning, Dziuban, Hartman, and Moskal (2004) suggest that blended learning implementations should involve: "a shift from lecture- to student-centered instruction in which students become active and interactive learners (this shift should apply to the entire course, including the face-to-face contact sessions); increases in interaction between student-instructor, student-student, student-content, and student-outside resources; and integrating formative and summative assessment mechanisms for students and instructor" (p. 3).

In recent years, blended learning has gained increasing popularity and has been increasingly adopted as an instructional method. In fact, many have noted and suggested blended learning to be one of the key developments in education in recent years (Garrison & Kanuka, 2004; Watson, 2008). Despite the challenges and limitations associated with blended learning implementations (Stubbs, Martin, & Endlar, 2006; Vaughan, 2007), research has documented that blended learning affords a number of benefits such as: improving student convenience and engagement (Owston, York, & Murtha, 2013); increasing teacher-student interaction (Vaughan, 2007); reducing dropout rates (López-Pérez, Pérez-López & Rodríguez-Ariza, 2011); improving student satisfaction (So, 2009). Most importantly, prior research has shown positive associations between blended learning and academic performance (Allen et al., 2007; Bernard et al., 2014; Deschacht, & Goeman, 2015; López-Pérez et al., 2011).

While the body of work examining the effects of blended learning continues to grow, however, research focusing on CEGEP students remains scant. As such, the present paper addresses this gap by investigating the blended learning implementation in the context of a Mechanics course at a CEGEP. The present study is part of our ongoing effort to better understand the impact of alternative instructional approaches in the CEGEP context and builds on our previous work (Bazelais & Doleck, 2018) that sought to understand the impact of blended learning on students' understanding of complex concepts, acquisition of key skills, and attitudes toward the instructional approach.

Method

Context

This comparative case study (as illustrated in Table 1) examines the differences in student academic performance between a traditional lecture-based class (control group) and the flipped classroom model of blended learning (treatment group) in a college Mechanics course. Mechanics is the first physics course of the three required physics courses for pre-university science students. The Mechanics course, which introduces students to the basic concepts and principles of Newtonian Mechanics, spans 75 hours (45 hours of lectures and 30 hours of laboratory periods) and consists of two 1.5-hour lectures (3 hours/week) and one 2-hour laboratory session per week. Furthermore, the overall evaluation is identical to both groups (blended and control), for example, three-unit tests weighted at ten (10) percentage points for a total of 30%, 20% for laboratory experiments, 10% for weekly out-of-class assignments, or in-class quizzes, and 40% for a standardized final exam common to both sections, except for the use of in-class quizzes in the blended format instead of weekly out-of-class assignments.

As mentioned earlier, blended learning can be implemented in many ways, such as the flipped classroom, which can shift direct instruction from the classroom to the online environment using online videos (Bergmann & Sams, 2012). The flipped classroom approach provides a means to foster active learning strategies by maximizing time on task, class time dedicated to problem-solving, and deep conceptual understanding (Bergmann & Sams, 2012; Mazur, 2013; Means et al., 2013). According to Dziuban et al. (2014), blended learning should be understood not simply as a temporal construct but rather as a fundamental redesign of the instructional model with a shift from lecture to student-focused pedagogy emphasizing active and interactive learning strategies. In the blended learning approach, instead of lecturing for the full hour and twenty minutes as in the control group, some of the in-class lectures were directed online using asynchronous video lectures. Thus, there was no out-of-class homework assignment associated with the blended course other than the online video lectures. In the blended context, in-class quizzes were used to replace the weekly out-of-class homework assignments with the emphasis on active learner classroom. As a result, the in-class time was used to discuss concepts found in the video lectures (5 minutes), followed by MS PowerPoint mini-lecture (10-15 minutes) with the aid of a SMARTBoard to revisit the concepts posted in the video lectures and clarify remaining misconceptions. The remaining class time was then spent on classroom discussion, problem-solving strategies, in-class quizzes, with the co-presence of the teacher while students collaboratively co-construct knowledge. In addition, students would be quizzed every week on that week's concepts. Students would get to work individually on the quiz for ten minutes, and then an additional ten minutes would be given to them where they could work together on the two-stage quiz with their peers to co-construct and share their understanding. The treatment group was told not to purchase the compulsory textbook, and however, if they needed to, they could use any reference physics text or online resource.

In contrast, the traditional lecture course (control group) had the required textbook coupled with weekly readings and out-of-class homework assignments but no weekly quizzes. The primary mode of instruction in the control group was a PowerPoint lecture for a full 1 hour and 20 minutes, including conceptual questions and problem-solving examples. Both the treatment and the control groups had identical content, and the PowerPoint slides and videos were made available online to both groups simultaneously. However, the videos were only supplemental for the control group and were not required as part of the course. Instead of weekly videos and quizzes (as in the treatment group), students in the control group had traditional readings and weekly out-of-class homework assignments.

The outcome measures (illustrated in Table 1) include: The Force Concept Inventory (FCI) and the final exam averages (FX AVG). The FCI is used to evaluate the students' knowledge state before and after instruction. The FCI consists of two tests: (a) a physics diagnostic test to evaluate the student's conceptual understanding of common physical phenomena, and (b) a mathematic diagnostic test to assess the student's mathematical skills; both tests are recommended for use as pre-tests to measure the student's initial knowledge state (Hestenes, Wells, & Swackhamer, 1992, p. 2).

Table 1

Study Conditions

Sections	Condition	Outcome Measures
Treatment group	Blended learning approach	FCI, FX AVG,
Control group	Traditional Lecture Format	FCI FX AVG

Note. Both sections were taught by the same instructor

Participants

After obtaining ethics approval, the study was conducted by obtaining consent from participants. The participants in the present study were first year pre-university science students at an English CEGEP in Montreal. The sample (*n* = 71, 52% males, 48% females) came from two sections of the Mechanics course. No systematic differences between the two groups were found (Table 2). The HSA was same for the control group (*n* = 34, HSA = 75.52%, Std.

Deviation = 7.56) and the treatment group (*n* = 37, HSA = 74.74%, Std. Deviation = 9.23). A one-way ANOVA revealed that the two groups were not significantly different (*p* = .*133*), at the beginning of the Mechanics course.

Table 2

The Sample and Study Conditions

Sample		Treatment Group	Control Group
N		37	34
Gender	Male	57%	47%
	Female	43%	53%
High School Average (HSA)		74.74%	75.52%

Note. A one-way ANOVA shows no significant differences, *p* =.133

Instruments and Measures

Data instruments and measures consisted of the FCI pre-and post-test results, aggregate high school grades, and final exam grades in the Mechanics course, as well as the computed average normalized learning gain (conceptual change) from the FCI pre- and post-test results as per Hake (1998).

Analysis and Results

The data was analyzed using ANCOVA to examine the effect of a blended course (treatment) vs. traditional course (control) and gender on academic performance (ex. FCI post-test and final exam score), while controlling for the effect of prior knowledge by including pre-test scores and high school average (HSA) as covariates. A 95% confidence interval was used for all statistical analysis. In addition, this subsection reports the FCI post-test results using the average normalized gain formula, g, as per Hake's (1998) measure of conceptual change. Using the research-based normalized gain formula as per Hake (1998) to measure college physics students conceptual understand or learning gains, and as well as the observed effect of gender, is congruent to several other empirical studies (see Coletta et al., 2012; Coletta & Phillips, 2005; Hake, 2002 & 1998; Lasry, Mazur, & Watkins, 2008; Savinainen & Scott, 2002). Moreover, the FCI gain analysis is well-documented in the science education literature, and consequently, a research-based conceptual inventory is often used to measure first-year university students' conceptual understanding before and after instruction in introductory science courses (Coletta et al., 2012; Hake 1998 & 2002; Lasry, Mazur, & Watkins, 2008).

The first step was to analyze the FCI pre-and-post test results using the normalized gain formula <g> to compare the blended learning course with the non-blended learning course (that is, courses making little or no use of online resources, blended learning, or interactive engagement methods, and relying largely on passive student lectures). This part of the analysis attempted to answer the primary research question, "Does a blended approach lead to more conceptual change or gain (as measured by the FCI) and higher performance on the standardized common final exam?" In other words, we sought to examine whether students in the course that use a blended learning approach to promote conceptual understanding and activities and provide immediate feedback through discussion with peers perform better in both the FCI and the standardized common final exam?

The second step of the data analysis looked exclusively at the academic gains resulting from the implementation of the blended learning approach. Lastly, the third step of the data analysis looked exclusively at the ANCOVA to examine the effect of blended learning on academic performance (ex. FCI post-test and final exam score) as dependent variables and FCI pretest score as a covariate while controlling for gender. We do so to assess the impact of the blended learning approach on students' learning outcomes and academic performance. This subsection of the research used data collected from high school and CEGEP and overall academic results to answer all the relevant research questions.

FCI Inventory Scores

Both the treatment and the control group took the FCI in the first week and the last week of the semester as pre-and post-diagnostics. The FCI pre- and post-tests data were statistically tested to determine whether the blended learning course leads to more conceptual change or gain, as measured by the average normalized gain formula <g>. For the treatment group, the blended learning approach was implemented for the entire semester. In contrast, the traditional lecture-based format was implemented for the control group, with identical contents and online assignments, and the video lectures posted online for students as supplementary resources. The results are displayed in Table 3 in the form of pre-and post- FCI average total score in percentage, standard deviation, and the average normalized learning gain, <g>.

Table 3

FCI inventory scores

Sections	FCI Pretest % (S. Dev.)	FCI Posttest % (S. Dev.)	Average Normalized Gain % Hake's $g = \frac{pretest - posttest}{100 - pretest}$
Treatment group	37.43 (20.26)	62.28 (17.53)	40 %
Control group	42.03 (15.68)	54.44 (17.98)	22 %
ANOVA results	p = .292	p = .072	p = .002*

Note. *p <.05

According to Hake (1998), interactive engagement learning environments have average gains of about 52%, whereas the traditional lecture-based format has average gains of about 22%. A one-way ANOVA shows that the average normalized learning gains of 40% for the treatment group as compared to the gain of 22% for the control group is statistically significant, F (1, 69) = 10.25, p = .002, confirming that a blended course coupled with pedagogically sound instructional strategies in science education produces more effective learning gains.

Furthermore, An ANCOVA was conducted to examine the effects of the treatment (versus control group) and gender on the post-test scores, while controlling for the effect of prior knowledge by including pre-test scores as a covariate. The use of pretest scores as covariates is congruent with several studies (see Abdelraheem & Ahmed, 2015; Ardianti et al., 2020; Baepler et al., 2014; Gambari et al., 2018; Riffell & Sibley, 2005; Toth et al., 2009). As assessed by Levene's homogeneity of variance test, homogeneity of variance was observed (p = .443). After controlling for the FCI pretest score, there was a statistically significant difference in the FCI post-test results between the two groups, F (1, 66) = 10.90, $p < .002$, η^2 = .142. A post hoc analysis was performed with a Bonferroni adjustment indicating that the FCI post-test result was significantly greater in the treatment group compared to the control group (mean difference of 10.89 (95% CI, 4.31 to 17.48), $p < .005$). While there were statistically significant differences between the two groups for the FCI-pre-test, F (1, 66) = 45.64, $p < .001$, η^2 = .409, there was no statistically significant effect of gender, F (1, 66) = .014, p =.906, or interaction of group and gender, F (1, 66) = 1.59, p =.212, as illustrated in Table 4

Table 4

ANCOVA Analysis of Test Between Subjects with Pretest as the Covariate and Post-test as the Dependent Variable

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	10411.109[a]	4	2602.777	13.871	<.001	.457
Intercept	11474.87	1	11474.87	61.151	<.001	.481
FCIPRE	8563.867	1	8563.867	45.638	<.001	.409
Group	2045.645	1	2045.645	10.902	.002	.142
Gender	2.64	1	2.64	.014	.906	.000
group * gender	297.87	1	297.87	1.587	.212	.023
Error	12384.72	66	187.647			
Total	265405.2	71				
Corrected Total	22795.83	70				

a. R Squared = .457 (Adjusted R Squared = .424)

Final Exam Scores

As illustrated in Table 5, the performance on the standardized common final exam (FX) was higher for the treatment group (*M* = 64%, *SD* = 10.73) compared to (*M* = 56%, *SD* = 15.26) the control group. An ANCOVA was also conducted to examine the effects of the treatment (versus control group) and gender on final exam scores, while controlling for the effect of prior knowledge by including pre-test scores as a covariate. As assessed by Levene's homogeneity of variance test, homogeneity of variance was observed (p = .274). After controlling for the FCI pretest score, there was a significant difference in the standardized final exam results between the two groups, F (1, 66) = 6.47, p = .013, η^2 = .089. A post hoc analysis was performed with a Bonferroni adjustment indicating that the final exam result was significantly greater in the treatment group compared to the control group (mean difference of 8.06 (95% CI, 1.73 to 14.38), p =.013). While there were statistically significant differences between the two groups on the final exam result, there was no statistically significant effect of gender, F (1, 66) = 1.53 p =.220, or interaction of group and gender, F (1, 66) = .691 p =.409, (see Table 6).

These findings suggest that blended learning is a more effective instructional strategy for science learning (Bernard et al., 2014; Drysdale et al., 2013; Means et al., 2013; Spanjers et al., 2015; Stockwell et al., 2015; Vo et al., 2017). Furthermore, these findings suggest that traditional lecture-based instruction is a less effective tool for science learning. Finally, both the FCI post-test results and final exam average for the treatment group highlight the efficacy of the flipped classroom model of blended learning on students' learning outcomes.

Table 5

The overall final exam results and the number of students who failed per sections

Winter 2014	FX results %	# of students <60% (FX)	# of students that failed Mechanics	# of students (n)
Treatment group	64	12	5	37
Control group	56	20	11	34

Note. An ANCOVA shows the FX results are significant, $p < .05$

Table 6

ANCOVA Analysis of Test Between Subjects with Pretest as the Covariate and Final Exam as the Dependent Variable.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1568.021[a]	4	392.005	2.267	.071	.121
Intercept	39005.696	1	39005.696	225.542	.001	.774
FCIPRE	1.951	1	1.951	.011	.916	.000
Group	1118.872	1	1118.872	6.47	.013	.089
Gender	265.339	1	265.339	1.534	.220	.023
group * gender	119.544	1	119.544	.691	.409	.010
Error	11414.176	66	172.942			
Total	271591	71				
Corrected Total	12982.197	70				

a. R Squared = .121 (Adjusted R Squared = .067)

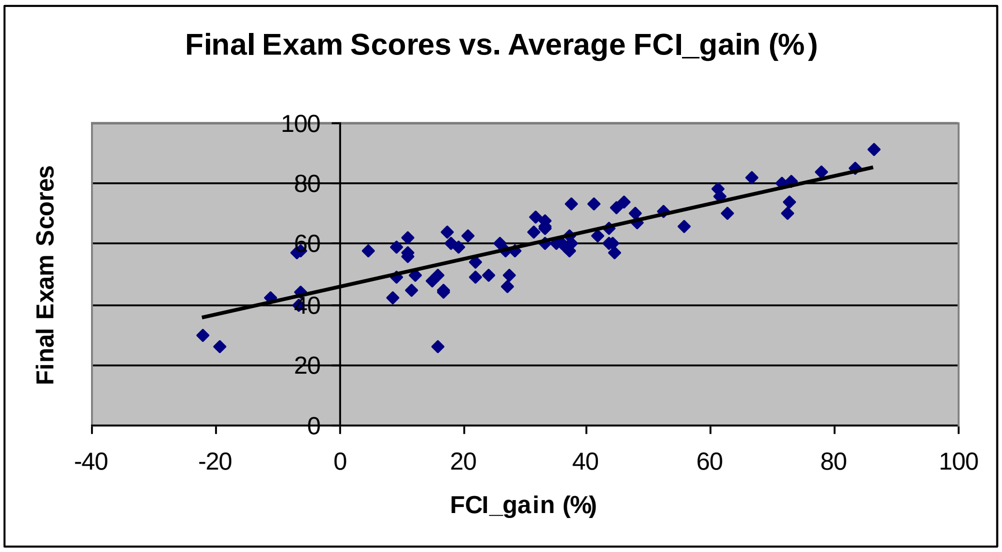
Between the two sections of Mechanics, the treatment group had a higher overall success rate (86.5%) compared to the control group (68%). Not only did the students in the treatment group do significantly better on the standardized common final exam—64% compared to 56% for the control group—but they performed slightly better on both the standard physics word problems and the conceptual multiple-choice component of the standardized common final exam—68% compared to 58% and, 60% compared to 54%, respectively. Both the standard physics word problems scores (F (1,69) = 1.50, p = .021) and the conceptual multiple-choice component (F (1,69) = 7.82, p = .006) of the standardized final exam between the two sections were statistically significant. Not only did students gain better conceptual understanding and acquire more skills, but their overall performance on the standardized final exam also improved, aligning with previous literature (e.g., Dori & Belcher, 2005; Pereira et al., 2007).

The data were further analyzed in order to determine the major factors that influence students' performance and whether there was a correlation between high school grades *(M = 75.13%, SD = 8.39)* and higher performance *(M = 60%, SD = 13.62)* in Mechanics (Physics NYA). A comparative analysis of the data confirms a strong correlation, r (71) = .57, p < .001, between high school grades and higher performance in Mechanics. This result implies that HSA or past academic achievement is a good predictor of higher performance in an introductory college science course.

As indicated in Figure 1, the data shows that students' final exam marks in Mechanics are strongly correlated with their conceptual understanding, as measured by the average normalized learning gain <g>, r (71) = .845, p =.000. While students' conceptual understanding is highly correlated with their performance in the final exam, the data also indicates that weaker students who failed to master Newtonian concepts had a negative gain in the FCI pre-post test results (see figure 1). The strong correlation between conceptual change (average FCI_gain) and final exam marks supports the view that problem-solving skills and performance are enhanced when students acquire a deep conceptual understanding (c.f. Biggs, 1999; Dori & Belcher, 2005; Hake, 1998; Lorenzo et al., 2006).

Figure 2

Final Exam Scores vs. Average FC_gain(%)



Further analysis revealed that the FCI pre-test average score for both groups combined (treatment and control) at the beginning of the semester was higher for males (45%) compared to females (34%), and a one-way ANOVA revealed that the FCI pre-test score between males and females students was statistically significant, (F (1, 69) = 6.89, p = .011). While the mean FCI pre-test score was statistically significant between male and female students, both the FCI post-test average score (F (1, 69) = 2.74, p = .103), and the standardized final exam average (F (1, 69) = 1.87, p = .176) were not statistically significant for the two groups. The overall conceptual gain (as illustrated in Table 7) after instruction was essentially the same for both males (*M = 32%, SD = 26.17)* and females *(M = 31%, SD = 22.62)* in both groups.

Table 7

Overall average FCI pre-and post-test and gain (%) by gender for both sections

Gender	*FCI-Pre-test*	*FCI Post-test*	*FCI_gain (%)*	*FX Score*
Males	45%	62%	32%	63%
Females	34%	55%	31%	58%
ANOVA results	p = .011*	P = .103	p =.876	P =.176

Note. * $p < .05$

In contrast, the FCI pre-test average score for the treatment group at the beginning of the semester was higher for males (45%) compared to females (28%), and a one-way ANOVA revealed that the FCI pre-test score between males and females students was statistically significant, (F (1, 36) = 7.68, p = .009). While the mean FCI pre-test score was statistically significant between male and female students, both the FCI post-test average score (F (1, 36) = 1.29, p = .264), and the standardized final exam average (F (1, 36) = .199, p = .658) were not statistically significant in the treatment group (blended learning course). Moreover, the overall conceptual gain (as illustrated in Table 8) in the treatment group after instruction was (*M = 37%, SD = 23.37)* for males, and *(M = 42%, SD = 18.72)* for females, whereas the overall conceptual gain in the control group (as illustrated in Table 8) was (*M = 25%, SD = 28.33)* for males, and (*M = 19%, SD = 20.77)* for females. Although the overall conceptual gain was higher for female students in the treatment group, but the result was not statistically significant, F (1, 36) = .436, p = .513. In contrast, the results for the control group were not statistically significant between the genders across all the examined variables (See Table 9).

Table 8

Average FCI pre-and post-test results and FCI_gain (%) by gender for the blended learning approach

Gender	*FCI-Pre-test*	*FCI Post-test*	*FCI_gain(%)*	*FX Score*
Males	45%	65%	37%	65%
Females	28%	59%	42%	63%
ANOVA results	p = .009*	p = .264	p =.513	p =.658

Note. * $p < .05$

Table 9

Average FCI pre-and post-test results and FCI_gain(%) by gender for the control group

Gender	*FCI-Pre-test*	*FCI Post-test*	*FCI_gain(%)*	*FX Score*
Males	44%	58%	25%	60%
Females	40%	51%	19%	53%
ANOVA results	*p* = .384	*p* = .271	*p* =.526	*p* =.201

Note. A one-way ANOVA shows no significant differences, p>.05

As previously stated, the overall conceptual gain was 40% in the blended learning course (treatment group) and 22% in the lecture format (control group). These findings highlight that both male and female students benefit from a blended learning course. The findings align with others (Lorenzo et al., 2006; Zhang, Ding, & Mazur, 2017), who submit that student-centered pedagogy has the potential to reduce the gender gap in physics performance and overcome some of the pre-instruction gender differences. Lorenzo et al. (2006) posited that teaching methods that foster an interactive environment are beneficial to both male and female students, but their findings suggest that effective pedagogy is central to boosting performance and reducing the gender gap in college physics education.

Concluding Remarks

Little is known about the impact of blended learning on students' learning outcomes in the context of CEGEPs. The present study investigated the difference in students' learning outcomes (standardized common final exam) between the flipped classroom model of blended learning and the traditional lecture format in a college Mechanics course while controlling for gender and HSA. The ANCOVA results show that the learning outcome for the treatment group compared to the control group is statistically significant, F (1, 66) = 6.47, p = .013, η^2 = .089. Thus, the findings suggest that implementing a well-designed flipped classroom blended learning model can positively impact students' learning outcomes. Notably, students in the blended learning group appeared to experience greater learning outcomes than those in the traditional lecture approach. This overall finding is consistent with and reinforces prior literature that has documented positive associations between the flipped classroom model of blended learning and academic performance (e.g., Allen et al., 2007; Bernard et al., 2014; Deschacht, & Goeman, 2015; López-Pérez et al., 2011).

Furthermore, this study also examined the existence of gender differences. The results suggest that the FCI pre-test results were significantly higher for males (45%) than females (34%), and the ANCOVA reveals that the difference in the FCI pre-test scores was statistically significant, F (1, 66) = 45.64, p < .001, η^2 = .409. The results illustrate that male students on average have a higher conceptual understanding of Mechanics concepts than females before instruction. In contrast, both the FCI post-test average score and the standardized final exam average were not statistically significant between the genders. These findings suggest that compared to male students, female students benefitted more after instructions in science education. As such, these findings suggest that an effective blended classroom approach can potentially improve female students' performance and help reduce the gender gap in physics education.

A few limitations in the present study need to be highlighted, which also provide avenues for future work. Immediate limitations of the present study concern the generalizability because of the study's use of convenience sampling and small sample size. Additionally, this investigation was conducted in the context of a particular course (i.e., Mechanics) at a single English CEGEP. As such, future research could draw a larger sample size and include participants from other courses as well. Further, future extensions of the study ought to consider the length of the approach, that is, examine the effects of blended learning over semesters rather than just within a particular semester. An important finding in our present study related to gender differences, which highlights the need to clarify why female students benefitted more from the blended learning approach. Moreover, to get a better understanding of what elements of the blending learning approach were most widely used, future works could focus on the components of the blended learning approach. Finally, in future research, qualitative data could be gathered to further clarify and complement the quantitative analysis to better understand the effects of blended learning in more detail.

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Bridging Text

A large body of work documents the link between blended learning and academic performance. However, most recent work primarily focuses on comparative studies that illustrate the influence of blended learning on learner outcomes, mainly, in terms of academic performance as measured by objective factors such as overall course grades, GPAs, final marks or course grades, and end-of-course evaluations. In Study 1, the prevailing perspective was exploited to examine the relationship between blended learning and academic performance in an understudied pre-university students' population, including the influences of two additional constructs: a conceptual pre-and post-tests and a standardized end-of-semester assessment. The findings of study 1 reveal that blended learning leads to more conceptual change and higher performance in STEM education, more importantly, it helps reduce the gender gap in an introductory science course. This overall finding (study 1) is consistent with and reinforces prior literature that has documented positive associations between blended learning and academic performance.

In contrast, Study 2 and 3 builds on the findings of study 1 and previous work by examining the impact of instructional pedagogical design and support for cognition and academic performance in a blended learning context. In the next section, study 2 examines the impact of frequent two-stage quizzes and peer formative feedback in blended learning situations on performance. A two-stage quiz is a pedagogical strategy that allows students to work on a quiz for 10-15 minutes individually, and then an additional 10 minutes is allocated to group discussions with peer formative feedback (See Bazelais and Doleck, 2018a, 2018b; Bazelais, Doleck, & Lemay, 2019a, 2019b). Accordingly, study 2 contrasts between two sections of E&M, where the blended learning context (treatment) uses frequent two-stage quizzes as a moderator with peer formative feedback, while the control group uses the lecture format with online homework & instant feedback. Whereas study 3 examines the impact of asynchronous online video instructions with online homework & instant feedback in blended learning situations on performance. Study 3 contrasts two sections of Waves, where the blended learning context (treatment) incorporates asynchronous online video instructions with online homework & instant feedback, whereas the control group only uses the traditional lecture presentation with online homework & instant feedback. In doing so, the study fulfills an important gap in the literature related to the lack of instructional pedagogical investigations, in addition, to extending the body of work to an understudied educational setting.

Chapter 3: Study 2 & 3

Investigating a Blended Learning Context that Incorporates Two-stage Quizzes and Peer Formative Feedback in STEM Education

Bazelais, P., Breuleux, A., & Doleck, T. (2020). (*in preparation*). Investigating a Blended Learning Context that Incorporates Two-stage Quizzes and Peer Formative Feedback in STEM Education

Abstract

Researchers have expressed concern about the state of STEM education. To improve this situation, new pedagogies, such as blended learning have been proposed and tested. The last decade has seen an increase in the use of blended learning to support student learning and enhance engagement in STEM education; however, the effect of blended learning on teaching and learning remains unclear and often mixed. This manuscript reports on two studies. The studies draw on data from pre-university science students in the following two courses: (1) Electricity and Magnetism and (2) Waves, Optics & Modern Physics. In study 1, the treatment group (blended learning with two-stage quizzes & peer formative feedback) performed significantly higher than the control group (lecture format with online homework & instant feedback) in the standardized final exam. In contrast, in study 2, there was non-significant main effect of groups, indicating that the treatment group (blended learning with online homework & instant feedback) and the control group (lecture format with online homework & instant feedback*)* performed similarly in the standardized final exam. The finding of study 1 suggests that the effect of robust quizzes and peer formative feedback in a blended learning context improves performance in STEM education. Whereas the finding of study 2 suggests that a blended learning context that only uses online video lectures without incorporating any instructional framework or support for cognition other than the lecture is comparable to a traditional FTF course.

Keywords: Pedagogy, Two-stage quizzes, Blended learning, Performance, Peer formative feedback, STEM education.

Introduction

The prominence of science, technology, engineering, and mathematics (STEM) has been well-documented in both the educational literature and the media because of its essential role in shaping the knowledge-based economy or technical labor force of the future. The STEM field plays a critical role in national security, global competitiveness, economic growth, and in building the foundational skills needed of the 21st century (Koutsopoulos, 2019; Langdon et al., 2011; U.S Bureau of Labor Statistics, 2009). STEM education is vital to our future and the workforce and remains the fastest growing sector of the economy. The STEM field is growing at 17%, while others at 9.8% (Koutsopoulos, 2019; Langdon et al., 2011), and is accountable for 6.2% of overall employment in the United States (Fayer et al., 2017). Despite the increased interest and importance placed on the STEM field by both researchers and policy makers, the number of students pursuing STEM programs or completing STEM degrees continues to be a concern. Whereas the number of well-prepared students interested in pursuing the STEM field is rising, there is high attrition rate (Akiha et al., 2018; Eagan et al., 2014; Pryor and Eagan, 2013) once they enroll in colleges and universities. Overwhelmingly, 50% of STEM majors do not graduate or complete their bachelor degrees within 6 years of entering college (Akiha et al., 2018; Eagan et al., 2014), and the majority of them drop out within the first 2 years of college (Watkins & Mazur, 2013). The attrition rate is even higher at the 2-year college level, where two-thirds of STEM students do not graduate within 4 years (Van Noy & Zeidenberg, 2014). In order to address this problem, policy makers call for a 33% increase in STEM retention rates and more than one million STEM graduates by the year 2022 (Akiha et al., 2018; President's Council of Advisors on Science and Technology, 2012).

Researchers in STEM education note poor instruction (ex. teacher-focus instructional strategies) and the lack of academic support as some of the leading causes for the loss of interest and attrition in STEM (Akiha et al., 2018; Hains-Wesson & Tyler, 2015; Watkins & Mazur, 2013; Yarker & Park, 2012). Accordingly, more than 90% of students that dropout of STEM education source poor instruction as the primary reason for leaving, even more disturbing, 75% of the students who remain in the STEM field also cited poor instruction in science courses or the lack of student-faculty interaction as a major concern in STEM education (Hains-Wesson & Tyler, 2015; Watkins & Mazur, 2013). While a large percentage of students that dropout of STEM stress interest in another field as the primary motivation for dropping out, however, over 40% of students espouse poor quality of instruction as the principal reason for leaving the STEM field (Hains-Wesson & Tyler, 2015; Watkins & Mazur, 2013).

In the context of Quebec, the percentage of *Collège d'enseignement général et professionnel* (CEGEP—for a primer on CEGEPs, see Bazelais, Lemay, & Doleck, 2016) students completing the two-year pre-university program within the two-year period is persistently low, 31.70%; and, only 65% complete their CEGEP education within 4 years (SRAMP-PSEP, 2016). Likewise, 30% of CEGEP students are permanent dropouts and 35% do not graduate within 4 years, with the dropout rate being higher at 36% for males as compared to 25% for females (Report of The Action Group on Student Retention and Success in Quebec, 2009). Even more disturbing, 54% of male students drop out before obtaining a CEGEP diploma, a percentage that is more than double the national average of 22% (Statistics Canada, 2008). The stubbornly low retention rate in the STEM field poses a serious challenge (Chen, 2013) that affects the conduit of graduates in STEM programs and consequently the number of STEM graduates entering the technical labor force. Struggling to complete introductory STEM courses can consequence in loss of interest, conviction, and motivation, ultimately leading to a divergence away from the STEM discipline (Gasiewski, Eagan, Garcia, Hurtado, & Chang, 2011). Thus, it is imperative to examine why well-prepared students, who were previously interested in STEM, drop out or shift away from STEM programs at such an alarming rate. To remain competitive, innovative, and sustainable in this knowledge-based economy, both perseverance and academic achievement in STEM related programs must be addressed in future research. Furthermore, investigations of dispositions that affect the quality of instruction and student persistence and achievement outcomes are both timely and deserving of attention. Blended learning can better address the needs of STEM students because it has the potential to create a more positive and active learning environment through increased engagement, collaboration, and time on-task (Drysdale et al., 2013; Means et al., 2013; Spanjers et al., 2015). Indeed, blended learning is better to meet the needs of diverse student populations and learners with diverse learning styles, more importantly, improved learning outcomes (Drysdale et al., 2013; Means et al., 2013; Spanjers et al., 2015). The present study focuses on STEM courses that use blended learning—which combines face-to-face (FTF) classroom instruction with online-mediated instruction—in the context of CEGEP education and compared the effects of blended versus traditional learning modes on student academic performance.

Literature Review

Current science education research suggests that the traditional lecture-based instruction is a less effective tool for teaching and learning as compared to other forms of instructions such as interactive engagement or blended learning (Akiha et al., 2018; Caldwell, 2007; Crouch & Mazur, 2001; Duncan 2007; Hake, 1998; Mazur, 2013; Watkins & Mazur, 2013). Moreover, it fails to promote deep holistic learning outcomes (Koutsopoulos, 2019; Lee & Hung, 2012;

Orion, 2007). Despite the overwhelming research indicating that lecture-based instruction is less effective as a tool for learning (Akiha et al., 2018; Caldwell, 2007; Crouch & Mazur, 2001; Duncan 2007; Hake 1998), yet it remains the foremost instructional praxis in STEM education (Freeman, 2000; Stockwell et al., 2015; Wu, 2004). While this pedagogical methodology might be beneficial for some students, it is essentially ineffectual for many students, and largely responsible for the high attrition rate in STEM education (Akiha et al., 2018; Watkins & Mazur, 2013). However, realizing the limitations of the lecture and textbook contexts in STEM education, many researchers and educators have called for a shift in paradigm or alternative methodologies toward more student-centered approaches such as blended learning (Akiha et al., 2018; Hains-Wesson & Tyler, 2015; Stockwell et al., 2015). Consequently, over 90% of students who drop out in STEM education cited the lecture as the most uninspiring instructional strategy and the leading cause for dropping out of STEM programs, more critically, 75% of STEM majors refer to the lecture as the least effective means for teaching and learning (Akiha et al., 2018). While the lecture-based instruction is full of challenges and has been the predominant method in STEM education (Freeman 2000; Wu 2004), many researchers consider blended learning as a viable option for such improvements (Hains-Wesson & Tyler, 2015; Torrisi-Steele, 2011) because it has been shown to improve: collaboration, interaction, co-regulation, pedagogy (Järvelä & Hadwin, 2013), learning experiences, and better outcomes for students (e.g., Bernard et al., 2014; Ginder & Stearns, 2014; Hill et al., 2015; Larson & Sung, 2009; Lin et al., 2016; Means et al., 2013; Stockwell et al., 2015; Suana et al., 2019; Tamim et al., 2011; Vo, Zhu, & Diep, 2017).

The term blended or hybrid learning is defined as an instructional approach which "combines FTF and online learning modalities" (Halverson et al. 2014, p. 20). Staker and Horn

(2012) defined blended learning as: “a formal education program in which a student learns at least in part through redelivery of content and instruction via digital and online media with some element of student control over time, place, path, or pace" (p. 3). According to more recent studies of online learning, blended learning is defined as courses that combine online delivery of content and instruction—and FTF instruction with reduced number of FTF meetings—where 30% to 79% of the content is delivered online (Allen et al., 2016). Essentially blended learning is conceptualized as the use of two or more distinct methods of instructions which combine FTF instruction with technology-mediated instruction (Graham, 2006, 2009). More importantly, it refers to a learning context that requires profound modifications in the teachers' pedagogical stance (Raes et al., 2020; Ramsey et al., 2016) in order to accommodate a new generation of learners known as "digital natives," learners who "think and process information" in ways that are profoundly different from previous users (Prensky, 2001), moreover, learners who use computers or information and communication technologies (ICT) in their everyday life (Spanjers et al., 2015). As mentioned earlier, blended learning is better to meet the needs of diverse student populations and learners with diverse learning styles (Spanjers et al., 2015; Yapici & Akbayin, 2012). Within this context, it is argued that it is more beneficial to make the education system less reliant on location and time (Raes et al., 2020; Spanjers et al., 2015; Yapici & Akbayin, 2012). Consequently, the literature review reveals many compelling affordances of blended learning: flexibility in terms of place and time (Boelens et al., 2018); some element of control over their own learning and education (Spanjers et al., 2015); increased attendance and satisfaction (Stockwell et al., 2015); encouraging attitudes towards subject matter (Lin, Tseng, & Chiang, 2016), engagement with content (McLean, 2018), and customizable experience (Cuesta-Medina, 2018). Importantly, several studies have considered and illustrated the influence of blended learning on student learning outcomes (Bazelais & Doleck, 2018a, 2018b; Lin et al., 2016; López-Pérez, Pérez-López, & Rodríguez-Ariza, 2011; Stockwell et al., 2015; Suana et al., 2019).

Research on online education has documented that both the effectiveness and learning outcomes of blended learning conditions are equal or greater when compared to the traditional FTF or fully online conditions (Allen et al., 2016, 2017; Bernard et al., 2014; Means et al., 2013; Larson & Sung, 2009; Tamim et al., 2011). Furthermore, a large body of research reveals a significant positive effect of blended learning when compared to the traditional FTF or fully online conditions (Bernard et al., 2014; Demirer & Sahin, 2013; Larson & Sung, 2009; López-Pérez, Pérez-López, & Rodríguez- Ariza, 2011; Means et al., 2013; Spanjers et al., 2015). The effect of blended learning on academic performance is well documented in diverse contexts, e.g., higher education, secondary education, adult education, and workplace training (Bernard et al., 2014; Means et al., 2013; Schimd et al., 2014; Spanjers et al., 2015; Vo et al., 2017). According to a meta-analysis conducted by Bernard et al. (2014), students in the blended learning contexts perform better than FTF classroom instruction by one-third of a standard deviation ($g^+ = 0.334$, $k = 117$, $p <.001$). Their finding is also similar with other meta-analyses, for example, Means et al. (2013), found that students in blended learning contexts outperform those students in FTF conditions ($g^+ = +0.35$, $p < .0001$). Tamim et al. (2011) report that blended learning conditions were considerably more effective ($g^+ = +0.33$, $p = .00$, $k = 45$). A more recent meta-analysis by Vo et al. (2017) reveals a higher mean effect size for blended learning vs. FTF in STEM ($g^+ = 0.496$) compared to non-STEM disciplines ($g^+ = 0.210$). Their finding suggests that blended learning improves both the quality of instruction and academic performance in science education and, particularly, more effective than both traditional FTF and fully online learning. Essentially, blended learning conditions produce more meaningful learning experiences and superior learning outcomes compared to the traditional FTF classroom format, especially, in STEM education (Bernard et al., 2014; Liu et al., 2016; Means et al., 2013; Vo et al., 2017).

Findings on comparison studies suggest that blended learning improved learning outcomes (Bernard et al., 2014; Drysdale et al., 2013; Means et al., 2013; Larson & Sung, 2009; Tamim et al., 2011). According to Spanjers et al. (2015), these meta-analyses and studies include older studies dating as far back as the mid-nineties to 2010 and consequently, may have used different definitions to characterize blended learning. They argue that both the prominence of technology and the infrastructure have since improved in schools, for example, increased accessibility, improved technological tools, videos and animations, and other types of multimedia are available today. Furthermore, Friesen (2012) argues that only blended learning definitions from 2006 and onward should be considered topical or germane. Accordingly, all these factors may have confounded the results related to the effectiveness of blended learning and thereby, limit the overwhelming positive effects reported in these past studies and previous meta-analyses. More importantly, they may have had an adverse impact on the design and the implementation of the blended learning environments (Deperlioglu & Kose, 2013; Graham, 2013; Lee, Fong, & Gordon, 2013) and subsequently affect the effectiveness of blended learning and student satisfaction (Spanjers et al., 2015). A large body of research suggests that blended learning is likely to ascend as the leading paradigm of the future (Drysdale et al., 2013; Dziuban et al., 2018; Halverson et al., 2012, 2014). Indeed, blended learning is increasingly evolving as the “traditional model” or “new normal” (Dziuban et al., 2018; Norberg et al., 2011) in higher education, and as an area of research and practice (Halverson et al., 2012, 2014). This change can be considered “as an educational transformation or paradigm shift” (Dziuban et al., 2004, p. 1). Despite the prominence and positive effects of blended learning, there is still a gap—for example, the lack of coherence or a single accepted conceptual framework, discipline specific theories, the grasp of how and why blended learning is more effective is not entirely conclusive, and thus warrants further research (Graham, 2013).

Purpose of Study

Although blended learning methods are significantly more effective, can create a more positive and active learning environment, enhance both the quality of instruction, and student learning outcomes in STEM education, little is known about how such instructional strategies and practices affect learning outcomes in the context of CEGEP pre-university science students. While the effects of blended learning continue to gain popularity and widespread acceptance in the educational landscape, however, very little research has been conducted on pre-university CEGEP STEM students and on the impact of blended learning on academic performance in terms of end-of-semester assessment (Vo et al., 2017) such as a cumulative standardized final exam. The present study sought to address these gaps by examining the effectiveness of instruction in the pre-university science program at CEGEP, comparing the blended learning context and the traditional FTF instruction in terms of a standardized end-of-semester assessment. The findings of this research study will broaden the scope of the effectiveness of blended learning to other educational context and provide encouragement for future implementations and research in post-secondary education.

Overview of Studies

This manuscript consists of two studies of pre-university CEGEP students that contrasts learning outcomes from those in blended learning (treatment) versus traditional lecture format (control) classes, in the following science courses: (1) Electricity and Magnetism (E&M), and (2) Waves, Optics & Modern Physics (Waves). At the CEGEP where the studies are conducted, students enrolled in the 2-year pre-university science program, are required to take three compulsory physics courses, namely, (1) Mechanics, (2) E&M, and (3) Waves. Mechanics is the first semester physics course and introduces students to the fundamental concepts and principles of Newtonian Mechanics, leading to an understanding of translational and rotational kinematics, Newton's laws and the concept of force, torque, and conversation laws. E&M is the second physics course and introduces students to the fundamental concepts of electric charge and electric fields, leading to an understanding of circuit elements such as resistors, seats of *emf (electromotive force)* and capacitors, magnetic forces and fields. Waves is the third physics course and introduces students to the different types of oscillatory motion, waves, light, interference and diffraction, wave-particle duality and quantum theory, including special theory of relativity. Each of these courses has the same setup, for example, each course is 75 hours, divided into 45 hours of lectures and 30 hours of laboratory periods per semester, including course evaluations. There are two 1.5-hour lectures (3 hours/week) along with one 2-hour laboratory session per week. Upon completion of these compulsory courses the student will have the required physics prerequisites for the pre-university CEGEP science program, and as well as university.

Importantly, success in the latter physics courses (e.g., E&M and Waves) depends on a solid understanding of the underlying concepts introduced in the Mechanics course. Students who fail to grasp the fundamental concepts of Newtonian mechanics are usually ineffective in the subsequent E&M course. Therefore, it is imperative that students attain mastery of the fundamental concepts introduced in introductory science courses in order to be successful in the STEM field. It is suggestive that blended learning can create a more positive and active learning environment through increased engagement and time on-task, and subsequently help students achieve the necessary mastery by maximizing time dedicated to authentic problem-solving and deep conceptual understanding (Bergmann & Sams, 2012; Mazur, 2013). Study 1 contrasts between two sections of E&M, where the blended learning context (treatment) uses a comprehensive pedagogical framework such as frequent two-stage quizzes as a moderator with peer formative feedback while the control group uses the lecture format with online homework & instant feedback. A two-stage quiz is a pedagogical strategy that allows students to work on a quiz for 10-15 minutes individually, and an additional 10 minutes is allocated to group discussions with peer formative feedback (See Bazelais & Doleck, 2018a, 2018b; Bazelais, Doleck, & Lemay, 2019a, 2019b). Study 2 contrasts two sections of Waves, where the blended learning context (treatment) only incorporates asynchronous online video instructions with online homework & instant feedback, whereas the control group only uses the traditional lecture presentation with online homework & instant feedback. These studies sought to investigate the effectiveness of blended learning in the context of a standardized end-of-semester assessment such as a cumulative standardized final exam, including demographic characteristics such as gender in pre-university science students' population.

Study 1: The Electricity and Magnetism Physics Course

A comparative study contrasts two sections (treatment and control group) of the Electricity and Magnetism (E&M) Physics courses. In the blended learning format (treatment group), 40% of the FTF classroom lectures were replaced with asynchronous online video lectures. All the online videos, including the relevant lecture slides, were posted on the Omnivox portal with LEA[2] with a notification and an allocated time frame in which the students must watch the videos, especially before the next class session. Rather than assigning weekly homework (as was the case with the control group), the students in the treatment group were quizzed ten (10) times during the 15-week semester with no assigned homework outside of the classroom. Students were quizzed on average 3-4 times before each unit test, and the two-stage quizzes were designed not only to replace the out-of-classroom assignments but also to emphasize quality time-on-task and peer formative feedback.

In contrast, the traditional course with outside-of-class homework assignments served as the control group. The control group uses the lecture format to deliver the entire one hour and twenty minutes (1h 20 minutes) PowerPoint lecture with the aid of a SMARTBoard—interactive whiteboard that includes a computer, a projector, and applicable software. The PowerPoint lectures were identical for both groups and were posted simultaneously to the Omnivox portal with LEA. In addition, as part of their course requirements, students were expected to do outside weekly reading from the required text and online homework assignments using LON-CAPA—an open-source e-learning platform that delivers personalized online assignments and instant feedback for each student. However, the control group had no weekly quizzes. Table 1 illustrates the two conditions in the present study. The outcome measures (quizzes, unit tests, homework, and standardized final exam (FX)) are also listed for each condition.

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[2] LEA is a course management and communications system that allows for the distribution of documents and files, assignments, grade submissions, and discussion forum.

Research shows that in-class interactive quizzes are an effective educational tool, as they tend to increase students' level of engagement, attention, interaction, and attendance (Dobbins & Denton, 2017; Kay & LeSage, 2009; Raes et al., 2020). In addition, peer instruction and formative feedback promote the sort of "support for cognition" that encourages collaboration and more profound learning experiences (Elizabeth et al., 2012; Murphy et al., 2011; Watkins & Mazur, 2013). Accordingly, each quiz was designed with key concepts or learning outcomes that students must know and learn. For example, the two-stage quizzes comprised of both conceptual multiple-choice questions and word problems, as was the case for the outside-of-class homework assignment for the control group. Overall, students spent on average (10-15) minutes on the two-stage quizzes individually, and then an additional (10) minutes were allocated to group discussions that allow them to co-construct and share their understanding and give each other formative feedback. The two-stage quizzes were used to measure what students learned and understood from the course content and assess whether they could retain key underlying concepts throughout the semester. Research shows that low-stakes formative assessments (e.g., quizzes) coupled with peer interactive engagement improve academic performance when contrasted across diverse student populations in different class sections with various teachers (Haak et al., 2011; Hake, 1998; Roediger et al., 2011; Spanjers et al., 2015; Stockwell et al., 2015). Consequently, the blended learning format was designed to foster time-on-task with peer formative feedback, which are essential factors for promoting effective teaching and learning outcomes in STEM education.

Table 1

Summary of Methodology for Study 1

Sections	Condition	Outcome Measures
Treatment group	Blended format with reduced FTF meetings. 40% of the FTF lectures were replaced with asynchronous online video lectures coupled with in-class quizzes & peer formative feedback. No weekly outside-of-class homework	Quizzes, unit tests, FX
Control group	Lecture format combined with weekly outside-of-class homework assignment with no reduced FTF meetings	Outside-of-class homework assignment, unit tests, FX

Note. Each section was taught by a different instructor.

Different instructors taught both sections (treatment and control group) with identical content, lecture slides, including three required unit tests (e.g., test 1 on week 5, test 2 on week 10, and test 3 on week 15) and a cumulative standardized final exam at the end of the semester. The three required unit tests and the standardized final exam were identical to both sections. In addition, both the treatment and the control group were assigned identical practice problem sets and a free lab session where students could work together, ask questions, and address areas of misconceptions with the co-presence of the instructor before each unit test. Each of the three-unit tests is weighted at ten (10) percentage points for a total of 30% of their overall grade, while the standardized final exam is weighted at 40% overall. The remaining 30% is comprised of laboratory experiments (20%) and homework/quizzes (10%). The cumulative standardized final exam consists of 20 conceptual multiple-choice questions (20% weighted score) and 10-12 standard physics word problems (80% weighted score).

The blended format was advertised in the course catalogue, and students were made aware that they were expected to participate in both the FTF and online environments and to have reliable internet connections. Students were also made clear that they were expected to watch the online lectures by the due date or before the next classroom lecture session since they may contain critical concepts or assignments necessary and relevant for the next class session. In addition, participants of this study, both treatment and control groups, were informed of the confidential nature of the study and the data. They were assured that the study results would not be linked to any student's name or student I.D. number. The data was not analyzed until the final grades were submitted. The research participants gave their consent to the researcher to assess and measure teaching and learning effectiveness using their aggregate quizzes, homework, unit tests, and final exam marks.

Study Participants and Procedure

The target population for study 1 is first-semester college physics students at an English CEGEP in Montreal, Quebec. The sample ($N = 74$, 51% males, 49% females) was drawn primarily from two sections of the E&M Physics course. The treatment group consisted of $N = 36$ students (44% males, 56% females), whereas the control group consisted of $N = 38$ students (58% males, 42% females). In order to rule out systematic bias, comparative statistics were used to analyze the sample and the two sections of E&M that were part of this study. No systematic differences between the two groups were found (as illustrated in Table 2). The High School Average (HSA) was essentially the same for the control group ($N = 38$, HSA = 83.53%, $SD = 4.49$) and the treatment group ($N = 36$, HSA = 85.39%, $SD = 4.40$). A one-way ANOVA shows that these two groups were not significantly different $F\ (1,72) = 3.24$, $p = .076$), at the beginning of the semester. In addition, there was no significant difference between the genders, $F\ (1,72) = 0.81$, $p > .05$.

Table 2

Summary of the Sample, including Overall High School Average for each Group

Sample		Treatment Group	Control Group
N		36	38
Gender	Male	44%	58%
	Female	56%	42%
High School Average (HSA)		85.39%	83.53%

Note. A one-way ANOVA shows no significant differences, $p = .076$

Analysis and Results

An ANCOVA was conducted to examine the effects of the treatment (versus control group) and gender on final exam scores, while controlling for the effect of prior knowledge by including High School Average (HSA) scores as a covariate. Using HSA as a covariate is congruent with several studies (e.g., Asarta & Schmidt, 2017; Gebara, 2010; Goode et al., 2018; Nielsen et al., 2018; Owston et al., 2013; Owston et al., 2020). As assessed by Levene's homogeneity of variance test, homogeneity of variance was observed ($p = .472$). After controlling for HSA, there was a significant difference in the standardized final exam results between the two groups, F (1, 69) = 4.30, $p = .042$, $\eta^2 = .060$. A post hoc analysis was performed with a Bonferroni adjustment indicating that the final exam result was significantly greater in the treatment group than the control group (mean difference of 7.63 (95% CI, .288 to 14.97), $p = .042$). While there were statistically significant differences between the two groups on the final exam result, there was no statistically significant effect of gender, *F* (1, 69) = .127, *p* =.723, or between group and gender, *F* (1, 69) = .062, *p* =.805, as illustrated in Table 3. A supplemental ANCOVA was conducted with HSA as the covariate and unit tests average as the dependent variable. After adjusting for HSA, there was no statistically significant difference in the unit tests averages between the two groups, *F* (1, 69) = .627, *p* = .431, as illustrated in Table 4. In addition, there was no statistically significant effect of gender, *F* (1, 69) = .011, *p* =.917, or between group and gender, *F* (1, 69) = .218, *p* =.642, on the unit tests average.

Table 3

ANCOVA Analysis of Test Between Subjects with HSA as the Covariate and Final Exam as the Dependent Variable.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1202.000[a]	4	300.5	1.282	.286	.069
Intercept	715.293	1	715.293	3.05	.085	.042
HSA	6.528	1	6.528	.028	.868	.000
Group	1007.9	1	1007.9	4.298	.042	.059
Gender	29.781	1	29.781	.127	.723	.002
group * gender	14.429	1	14.429	.062	.805	.001
Error	16179.529	69	234.486			
Total	343007.44	74				
Corrected Total	17381.529	73				

a. R Squared = .069 (Adjusted R Squared = .015)

Table 4

Summary of unit test and final exam average for the two groups

Sections	Unit tests_avg % *(S. Dev.)*	Final exam % *(S. Dev.)*
Treatment group	74.00 *(14.80)*	70.40 *(15.18)*
Control group	72.76 *(12.12)*	62.50 *(14.85)*
ANCOVA results	$p = .431$	$p = .042$

These findings suggest that the blended learning context improves learning outcomes and produces superior overall performance than the traditional lecture format in STEM education. Similar results were observed by Stockwell, Stockwell, Cennamo, and Jiang (2015). The authors conducted an empirical study of blended learning versus traditional settings in STEM courses and found that blended learning context improves science education, and more importantly, in-class problem solving with formative feedback improves performance, and online video lectures increase attendance and satisfaction. They concluded that students who solved problems in class outperformed those students who only listened to a classroom lecture. Overall, they concluded that providing an environment for students to solve problems during class results in significantly better learning outcomes and academic performance, compared to simply having the same problems and solutions describe to them during the lecture. Consequently, learning environments such as those incorporating collaboration and active-based learning, and the facilitation of group interactions enable learning through the development of shared understanding of course topics (Dewey, 1938; Hmelo-Silver & DeSimone, 2013; Ramsden, 2003; Richardson, 2003).

Study 2: The Waves, Optics & Modern Physics Course

This comparative study was conducted to further test the effectiveness of a blended learning context that contrasted two sections of the college Waves, Optics & Modern Physics (Waves) course. Both the treatment and the control group were taught by different instructors and used identical unit tests and weekly online homework assignments with instant feedback using LON-CAPA. The blended format (treatment group) course replaced 40% of the FTF course contents using asynchronous online video lectures without incorporating any instructional framework or support for cognition other than the lecture. Whereas the control group only uses the lecture format as the primary mode of instruction. Furthermore, all the learning outcomes and assessment methods were common to both sections. Table 5 illustrates the two conditions in the present study. For each condition, the outcome measures (unit tests, online homework, and standardized final exam (FX)) are also listed.

Table 5

Summary of Methodology for study 2

Sections	Condition	Outcome Measures
Treatment group	Blended learning with reduced FTF meetings. 40% of the FTF lectures were replaced with asynchronous online video lectures coupled with online homework & instant feedback	Online homework assignments, unit tests, FX
Control group	Lecture format with online homework & instant feedback	Online homework assignments, unit tests, FX

Note. Each section was taught by a different instructor.

Study Participants and Procedure

The target population for study 2 is fourth-semester college physics students, and the sample (*N* = *80*, 49% males, 51% females) was drawn primarily from two sections of the Waves, Optics & Modern Physics (Waves) course. The treatment group consisted of *N* = *38* students *(*55% males, 45% females), whereas the control group consisted of *N* = *42* students (43% males, 57% females). In order to rule out systematic bias, comparative statistics were used to analyze the sample and the two sections of Waves that were part of this study. No systematic differences between the two groups were found (as illustrated in Table 6). The High School Average (HSA) was essentially the same for the control group (*N* = *42*, HSA = 81.76%, *SD* = 2.68) and the treatment group (*N* = *38*, HSA = 81.00%, *SD* = 3.38). A one-way ANOVA shows that these two groups were not significantly different $F\ (1,78) = 1.25$, $p = .266$), at the beginning of the semester. In addition, there was no significant differences between the genders, $F\ (1,78) = 0.036$, $p > .05$.

Table 6

Summary of the Sample, including Overall High School Average for each Group

Sample		Treatment Group	Control Group
N		38	42
Gender	Male	55%	43%
	Female	45%	57%
High School Average (HSA)		81.00%	81.76%

Note. A one-way ANOVA shows no significant differences, $p = .266$

Analysis and Results

An ANCOVA was conducted to examine the effect(s) of the treatment (versus control group) and gender on final exam scores, while controlling for the effect of prior knowledge by including High School Average (HSA) scores as a covariate. As assessed by Levene's homogeneity of variance test, homogeneity of variance was observed (p = .684). After controlling for HSA, there was no statistically significant differences in the standardized final exam results between the two groups, F (1, 75) = .021, p = .884, β = .052. In addition. there was no significant interaction effect between group and gender F (1, 75) = 1.14, p =.288, but there was significant effect of gender, F (1, 75) = 5.66, p =.020, η^2 = .070, as illustrated in Table 7. A post hoc analysis was performed with a Bonferroni adjustment indicating that the final exam result was significantly greater for males than females (mean difference of 7.08 (95% CI, 1.15 to 13.01), p =.020).

Table 7

ANCOVA Analysis of Test Between Subjects with HSA as the Covariate and Final Exam as the Dependent Variable

Source	Type III Sum of Squares	df	Mean Square	*F*	Sig.	Partial Eta Squared
Corrected Model	1271.628[a]	4	317.907	1.827	.132	.089
Intercept	163.349	1	163.349	.939	.336	.012
HSA	87.834	1	87.834	.505	.480	.007
Group	3.724	1	3.724	.021	.884	.000
Gender	985.363	1	985.363	5.663	.020	.070
group * gender	199.224	1	199.224	1.145	.288	.015
Error	13049.119	75	173.988			
Total	378888.25	80				
Corrected Total	14320.747	79				

a. R Squared = .089 (Adjusted R Squared = .040)

A supplemental ANCOVA was conducted with HSA as the covariate and unit tests average as the dependent variable. After adjusting for HSA, there was a significant difference in the unit tests averages between the two groups, F (1, 75) = 14.80, p <.001, η^2 = .165 but there was no statistically significant effect of gender, F (1, 75) = 1.89 p =.173, or between group and gender, F (1, 75) = 2.25 p =.138, on the unit tests average. A post hoc analysis was performed with a Bonferroni adjustment indicating that the unit test average was significantly greater in the control group compared to the treatment group (mean difference of 10.06 (95% CI, 4.85 to 15.26), p <.001), as illustrated in Table 8. Although the control group performed significantly higher in the overall unit test average, the treatment group performed significantly higher in the standardized final exam, indicating that the blended learning approach had a more lasting effect on students' learning outcomes. The overall findings of study 2 suggest that a blended learning context that only replaced part of the traditional FTF course (40%) with only online videos without incorporating a pedagogical framework or support for cognition such as interactive engagement or peer formative feedback is less effective and, thereby, resulted in comparable or equal learning outcomes or performance as compared to the traditional course. Furthermore, the findings also suggest that male students benefited more from an advanced blended learning science course.

Table 8

Summary of unit test and final exam average for the two groups

Sections	Unit tests_avg % *(S. Dev.)*	Final exam % *(S. Dev.)*
Treatment group	70.95 *(14.02)*	68.03 *(14.11)*
Control group	80.71 *(8.90)*	67.04 *(13.00)*
ANCOVA results	*p <.001*	*p = .884*

Discussion

The overall findings of study 1 suggest that the effect of robust quizzes and peer formative feedback in a blended learning context improves STEM education, that is, superior learning outcomes and better performance in a cumulative standardized final exam at the end of the semester. There was a significant main effect of groups, F (1, 69) = 4.30, p = .042, η^2 = .060, indicating that the treatment group performed significantly higher (mean difference of 7.63 (95% CI, .288 to 14.97), p =.0.042) than the control group in the standardized final exam. The findings suggest that a blended learning context leads to better long-term retention and more lasting learning outcomes. On the other hand, there were non-significant differences between the genders across all examined variables, indicating that both males and females performed equally in the standardized final exam. The findings reported above suggest that the traditional lecture and homework-based instructional strategy is a less effective tool for science learning and later retention. Furthermore, the findings of this empirical study suggest that the effects of frequent low-stake testing (e.g., quizzes) and peer formative feedback have a positive impact on the effectiveness of blended learning. Similar findings were observed by Spanjers et al. (2015), who concluded that the inclusion of quizzes positively impact the effectiveness and desirability of blended learning, more importantly, learning outcomes. It is suggestive that frequent testing can positively affect student learning outcomes by motivating the student's approach and attitude to study and to learning (Bazelais, Lemay, & Doleck, 2019a), and corrective feedback often provides useful information on the correct solution (Butler, Karpicke, & Roediger, 2008; Butler & Roediger, 2008; Spanjers et al., 2015). Within this context, it is suggested that quizzes and peer formative feedback increase both the effectiveness and magnetism of blended learning.

The positive effect of frequent testing (e.g., quizzes) (Adesope et al., 2017; Chen et al., 2018; Spanjers et al., 2015; Stockwell et al., 2015; Van Sickle 2015) and peer formative feedback (Bazelais, Lemay, & Doleck, 2019a, 2019b; Elizabeth et al., 2012; Murphy et al., 2011; Wentzel & Watkins, 2011) is well documented in the science literature. In the blended learning context, students could work individually (e.g., on in-class activities or quizzes), and then afforded the opportunity for peer corrective feedback, co-construction of knowledge, and shared-understanding. As the prevalence of blended learning receives widespread attention and becomes the "new normal", and calls for the need of greater student involvement and collaboration, self-regulation, and self-directed learning, it is, therefore, imperative for practitioners to provide students with the appropriate instructional content and strategies in the implementation of blended courses, for example, online activities, or video-embedded quizzes (Chen et al., 2018; Maciejewski, 2016; Murphy et al., 2016; Willis, 2014), in-class quizzes (Chen et al., 2018; Van Sickle, 2015), peer formative feedback (Bazelais, Lemay, & Doleck, 2019a, 2019b). Furthermore, it is crucial that educators or practitioners of blended learning consider and rethink the instructional design according to the learners' needs, employ the right methodology, use online activities and video embedded quizzes or in-class quizzes to ensure that students remain engaged and committed to the online environment, and more importantly, perform the online assignments within the allocated period. Nonetheless, students' success in a blended learning format is perhaps contingent on whether they perform the online activities within the allocated period.

It is suggestive that an environment that provides students with the opportunity to solve problems with increased peer corrective feedback during class results in significantly higher learning outcomes and academic performance, compared to simply having the same problems assigned to them as homework or answers describe to them during the course of the lecture. Furthermore, by incorporating interactive engagement and peer formative feedback in a blended course can address many of the challenge's students face in the traditional course. As a result, the blended course produces a more positive and active environment, enhances both the quality of instruction and learning outcomes, while addressing the overarching concerns of poor teaching quality and low retention rate in STEM education. The results further suggest how adopting an effective blended learning context can enhance student performance and, consequently, improve the quality of instruction in STEM related programs. Furthermore, of the findings suggest that blended learning methods can be adapted to foster quantifiable change and satisfaction in the science classroom, thereby, increasing student-student interaction, performance, and retention in the STEM field.

The findings of study 2 highlight that technology is a tool; when used effectively it can improve the quality of instruction and learning outcomes (Alammary et al., 2014; Aycock et al., 2002). The non-significant finding of this comparative study (F (1, 75) = .021, p = .884, β = .052). reiterates the notion that technology is simply a tool, that is, technology is neutral and not necessarily decisive. In fact, technology is less effective unless it is integrated with a sound pedagogical framework or whether the teacher feels competence and confidence using that technology (Ertmer et al., 2010; McGee & Reis, 2012). The overall finding supports the idea that an effective blended learning context that incorporates an instructional framework or support for cognition is significantly more effective than those contexts without technology (e.g., FTF) or only using the technology as an add-on. Similar findings were observed in prior studies (Swoboda & Feiler, 2016; Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011). The findings of study 2 suggest that simply putting videos or resources online does not necessarily lead to positive effects or outcomes. Furthermore, the findings further convey that thoughtful consideration should be taken when designing blended courses, especially, in the context of instructional pedagogical design and implementations. It is suggestive that a blended learning context that simply replaced or redirect some elements of the FTF classroom environment with online videos without any support for instructional foundations or cognition resulted in comparable or equal learning outcomes and performance as compared to a traditional course.

Limitations

The two studies are limited by their use of a non-randomized convenience sample. They are also limited due to the fact the instructors could not control for textbook access, the amount of time students spent online viewing the videos, or whether the videos were used as review materials for the final exam. Consequently, extra care should be taken in generalizing these results because of the small sample size, and the fact that the studies only contrasted two sections of the same courses during one semester. This is further supported by the non-significant gender differences in study 1 and non-significant effects found in study 2, a blended learning context that simply directed videos (40% of the content) to the online environment without the assimilation of a pedagogical framework or support for cognition other than the lecture is less effective. A larger sample size with participants representing multiple sections of the same courses for more than one semester, including both the Fall and Winter semesters for both English and French CEGEPs in Quebec could extend the findings. In addition, the cross-sectional nature of the studies limits the conclusions about the continual acquisition of knowledge or long-term retention.

Future directions

The present studies can be expanded by investigating a high-intensity blended learning context. Rather than modifying, replacing, or adding extra online activities or resources to the traditional course, alternatively, the entire course is built from the ground up where considerable proportion of the course content is directed to the online environment (Alammary et al., 2014). Furthermore, more research is required to investigate the proportion of time students spent in the online environment and whether the amount of time students spend online have any confounding effect on the effectiveness of blended learning contexts. Owston & York (2018) suggested that a blended learning context that delivers over 50% of the course contents online have greater overall student's satisfaction and performance. Research examining the predictors of blended learning effectiveness, for example, Kintu, Zhu, and Kagambe (2017), find student characteristics/backgrounds and design features to be significant predictors of student learning outcomes. The present study can also be extended by examining different pedagogical approaches and design models in the context of blended learning, and how these different models influence the pedagogical approaches use and time spent online, impact learners' across cognitive, social, and affective dimensions in order to better understand the effectiveness and the transformative potentials of blended learning, and the association between blended learning and performance and satisfaction in terms of lasting, long-term learning gains, and retention.

Conclusion

By examining the overall findings of blended learning on students' learning outcomes compared to the traditional course, we found a positive effect of blended learning in study 1, however, this difference was non-significant between the genders. In contrast, the overall finding in study 2 reveals a non-significant effect for a blended learning context which does not employ a conceptual framework or support for cognition. This blended context was less effective, that is, the learning outcome was comparable or equal to the traditional course. We discussed the results and offered implications for educational practice and research. The findings reported in the present study have broad implications for the blended learning literature. Consequently, this study provides researchers and practitioners of blended learning a potential framework for the application and implementation of blended learning models and designs to their teaching practice and research.

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Overall Discussion

As researchers and educators call for new pedagogical approaches to improve 21st century teaching and learning, particularly, in STEM education, blended learning has been promoted as one notable solution to this growing crisis. In the current literature, blended learning is recognized as a transformational new area of research and design that can address some of the challenges and limitations associated with the traditional lecture or fully online conditions, because it combines the best of both worlds and espouses best practices and benefits of these types of instructions (Keengwe & Kang, 2012; Spanjers et al., 2015). The impact of blended learning on academic performance has been well documented in diverse contexts, e.g., higher education, secondary education, adult education, and workplace training (Bernard et al., 2014; Means et al., 2013; Schimd et al., 2014; Vo et al., 2017) suggesting that blended learning is comparable or better than traditional FTF or fully online conditions. However, little is known about the impact of blended learning on students' learning outcomes in the context of CEGEPs.

In the present studies (study 1, 2, and 3), we investigated the effectiveness of instruction in the pre-university science program at CEGEP, comparing the blended learning context and the traditional FTF instruction. More specifically, the research sought to investigate whether a blended learning physics course that integrates evidence-based instructional practices and information communication technology (ICT) results in better performance on a cumulative standardized end-of-semester assessment in the three required physics courses (e.g., Mechanics, E&M, and Waves) of the pre-university science program.

In study 1, we investigated the difference in students' learning outcomes (standardized common final exam) between the flip classroom model of blended learning and traditional lecture approach in a college Mechanics course with pretest score as a covariate, while controlling for gender. we found a strong positive effect of blended learning. Study 1 suggest that the flip classroom model of blended learning can positively impact students' learning outcomes. Importantly, students in the blended learning group appeared to experience greater learning outcomes compared to the students in the traditional lecture approach. This overall finding is consistent with and reinforces prior literature that has documented positive associations between blended learning and academic performance (e.g., Allen et al., 2007; Bernard et al., 2014; Deschacht, & Goeman, 2015; López-Pérez et al., 2011).

Furthermore, study 1 also examined gender differences. The results illustrate that male students on average have a higher conceptual understanding of Mechanics concepts than females before instruction. In contrast, both the FCI post-test average score, and the standardized final exam average were not statistically significant between the genders. These findings suggest that compared to male students, female students benefitted more after instructions in science education. As such, these findings suggest that an effective blended classroom approach can potentially improve female students' performance and help reduce the gender gap in physics education.

The overall findings of study 2 suggest that a blended learning science course that integrated an evidence-based pedagogical framework such as robust quizzes and peer corrective feedback improves learning outcomes and resulted in better performance in a cumulative standardized (common) final exam at the end-of-the semester. The findings of study 2 reveal that the treatment group performed significantly higher than the control group in the standardized (common) final exam. On the other hand, there were non-significant differences between the genders across all examined variables, indicating that both males and females performed equally in the standardized final exam. The findings reported above suggest that the traditional lecture and homework-based instructional strategy is a less effective tool for science learning and later retention. Furthermore, the findings of this empirical study suggest that the effect of frequent testing (e.g., quizzes) and peer corrective feedback have a positive impact on the effectiveness of blended learning. Similar findings were observed by Spanjers et al. (2015), who concluded that the inclusion of quizzes positively impact the effectiveness and desirability of blended learning, more importantly, learning outcomes. Accordingly, research shows that frequent testing can positively affect student learning outcomes by motivating the student's approach and attitude to study and to learning (Bazelais, Lemay, Doleck, 2019a), and corrective feedback often provides useful information on the correct solution (Spanjers et al., 2015; Butler, Karpicke, & Roediger, 2008; Butler & Roediger, 2008). Within this context, it is suggested that quizzes and peer formative feedback increase the effectiveness of blended learning.

The non-significant finding of study 3 reiterates the notion that technology is simply a tool, that is, technology is neutral and not entirely decisive; and when used effectively it can improve the quality of instruction and learner outcomes (Alammary et al., 2014; Aycock et al., 2002). In fact, technology is less effective unless it is integrated with evidence-based pedagogical framework or whether the teacher feels competence and confidence using that technology (Ertmer et al., 2010; McGee & Reis, 2012). The overall finding of study 3 supports the idea that an effective blended learning context that incorporates an instructional framework or support for cognition is significantly more effective than those contexts without technology (e.g., FTF) or only using the technology as an add-on. Similar findings were observed in prior studies (Swoboda & Feiler, 2016; Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011). The findings of study 3 suggest that simply putting videos or resources online does not necessarily lead to positive effects or outcomes. Furthermore, the findings further convey that thoughtful consideration should be taken when designing blended courses, especially, in the context of instructional pedagogical design and implementations. The overall finding of study 3 leads to the conclusion that a blended learning context that simply replaced or redirected some elements of the FTF classroom environment with online videos without any support for instructional foundations or cognition resulted in comparable or equal learning outcomes and performance as compared to a traditional course.

In summary, it is suggestive that an environment that provides students with the opportunity to solve problems with increased peer corrective feedback during class results in significantly higher learning outcomes and academic performance, compared to simply having the same problems assigned to them as homework or answers described to them during the course of the lecture. Furthermore, by incorporating interactive engagement and peer formative feedback in a blended course can address many of the challenge's students face in the traditional course. The results also suggest that the effect of frequent quizzes and peer corrective feedback increase learner outcomes in science.

The positive effect of frequent testing (e.g., quizzes) (Adesope et al., 2017; Chen et al., 2018; Spanjers et al., 2015; Stockwell et al., 2015; Van Sickle 2015) and peer formative feedback (Bazelais, Lemay, & Doleck, 2019a & 2019b; Elizabeth et al., 2012; Murphy et al., 2011; Wentzel & Watkins, 2011) is well documented in the science literature. Within this context, it is suggestive that practitioners of blended learning provide students with the appropriate instructional content and strategies in the implementation of blended courses, for example, online activities or video-embedded quizzes (Chen et al., 2018; Maciejewski 2016; Murphy et al. 2016; Willis 2014), in-class quizzes (Chen et al., 2018; Van Sickle 2015), peer formative feedback (Bazelais, Lemay, & Doleck, 2019a, 2019b). Accordingly, self-regulation and self-directed learning are essential features that motivate students' learning (Zimmerman 2008 & 2011), and an effectual online-mediated instruction is critical to realizing the promise and the full potential of the blended learning context (Drysdale et al., 2013; Dziuban et al., 2018; Graham, 2012 & 2013, Halverson et al., 2012, 2014). Furthermore, it is highly crucial that educators or practitioners of blended learning consider and rethink the instructional design according to the learner's need, employ the right methodology, use online activities and video embedded quizzes or in-class quizzes to ensure that students remain engaged and committed to the online environment. Additionally, the findings suggest that blended learning methods can be adapted to foster quantifiable change and satisfaction in the science classroom, thereby, increasing student-student interaction, performance, and retention in the STEM field.

Limitations and Future Directions

While the three studies presented in the dissertation provide some meaningful insights and expand on the comprehension of blended learning, however, several pertinent questions warrant further investigation. Similarly, as with all research, there are overall underlying limitations that must be considered. While the limitations and future directions for each of the studies are addressed within the respective manuscripts, overall limitations and future directions are worth noting. Accordingly, some important limitations are outlined, and future research directions are proposed. Importantly, it must be underscored that the current body of work is exploratory, and findings must be interpreted with caution. Additional methodological limitations are also considered and underlined. For instance, the lack of theoretical foundations or instructional pedagogical design and implementation for research (Drysdale et al., 2013) can pose serious methodological challenges in the design, implementation, and application of blended learning.

The three studies are limited by their use of a non-randomized convenience sample. A few limitations in the present studies need to be highlighted, which also provide avenues for future work. Immediate limitations of the present studies concern generalizability because of the studies' use of convenience sampling and small sample size, and the fact that the studies only contrasted two sections of the same courses during one semester. The studies are also limited due to the fact that the instructors could not control for some confounding variables, for example, textbook access, the amount of effort or time students spend in the online environment, how many times the videos were viewed, or whether the videos were used as review materials for the cumulative standardized final exam. Additionally, this investigation was conducted in the context of a particular course (i.e., Mechanics, E&M, and Waves) at a single English CEGEP. A larger sample size with participants representing multiple sections of the same courses for more than one semester, including both the Fall and Winter semesters for both English and French CEGEPs in Quebec could extend the findings.

As such, future research could draw on larger sample sizes, include participants from other courses, and extend the investigation to other CEGEPs as well. Future extensions of the studies ought to consider the length of the approach, that is, examine the effects of blended learning over several semesters rather than just within a particular semester. Furthermore, more research is needed to study the impact of increased workload or required effort and time on investment, and as well as the benefits of blended learning (e.g., accessibility and convenience, opportunity, satisfaction, instructional design, self-regulated and directed learning, and cost effectiveness) on learner outcomes or academic performance. An important finding in our present studies related to gender differences, which highlights the need to clarify why female students benefitted more after instruction from a blended learning approach of a first semester introductory physics course. Moreover, to get a better understanding of what elements of the blending learning approach were most widely used, future works could focus on the components of the blended learning approach. Finally, in future research, qualitative data could be gathered to further clarify and complement the quantitative analysis to better understand the effects of blended learning in more detail. This can help clarify why a blended learning context that simply replaced part of the traditional FTF course with online videos without the assimilation of a pedagogical framework or support for cognition other than the lecture is less effective. In addition, the cross-sectional nature of the studies limits the conclusions about the continual acquisition of knowledge or long-term retention.

While blended learning is increasingly popular and perceived as the paradigm of the future, however, new forms of research methods are warranted to examine its effectiveness thoroughly and prompt some openings for new questions. For example, (1) how and why blended learning is more effective than other forms of learning or modalities? (2) how can theory inform design approaches and hands-on practices, (3) how to accurately measure its effectiveness on academic performance, (4) how increased workload, the amount of time student spent online, autonomy, self-regulation, and the purpose of technology moderate the effectiveness of blended learning on academic performance? More importantly, more research is needed to investigate the effectiveness of blended learning in other settings, particularly, in pre-university science students. Consequently, more research is needed to help educators better understand how to maximize the benefits, measure the effectiveness, address the challenges, and develop a conceptual framework to address the specificity and uniqueness of blended learning contexts.

Future Direction and Trends in the Covid-19 Era

The Covid-19 pandemic has compelled many schools, colleges, and universities across north America and the world, to discontinue traditional FTF classes, and transitioning fully to remote instruction and learning. This unforeseen disruption has led many schools, colleges, and universities to a state of turmoil while attempting to ameliorate the situation and adapt to a "new normal". Consequently, many educators were pressed to promptly adapt to this "new normal" with limited guidance and experience with online teaching and learning. Furthermore, they had to learn and adapt to new and emerging technologies (e.g., MS Teams, Zoom, Google Meetings, Webex, Skype, etc.) and educational tools during this pandemic and social-economic disturbance. Despite of all the recommendations and public discourse surrounding the Covid-19 vaccination, returning to normalcy and our traditional way of life, unfortunately, there is no going back to the pre-Covid-19 era. In fact, it is the time to adapt to the new reality and a 'new normal". Essentially, blended learning is ascertained to become the "traditional model" or "new normal" (Dziuban et al., 2018; Norberg et al., 2011) in higher education, and as an area of widespread practice and research (Halverson et al., 2012, 2014). Concomitantly, this unforeseen disruption also presents educators with a singular opportunity to rethink blended learning and examine how the exclusive utilization of remote education impacts pedagogy, learner outcomes, and performance in higher education.

As mentioned earlier in the dissertation, there are several distinct blended learning models and scope, ranging from low-, medium-, to high-intensity blends. Research shows there are many benefits of blended learning, however, its adoption can pose enormous challenges for educators, especially in terms of constructions and designs, implementations, sustainability, and scalability. The concept of blended learning remains ingenious and revolutionary in tenet;

nonetheless, it is sophisticated in practice (Lim & Wang, 2017; Wang, Han, & Yang, 2015). One key finding of the dissertation studies show that blended learning is more effective when evidence-based practices, educational theories of psychology (e.g., learner-centered and constructivist approaches to instruction), and support for cognition and technology guide the design process. Furthermore, technology plays an important role to blended learning environment and must equally be part of the design process. It is suggestive that technology rich-environment is more likely to foster change, especially, when the entire design process is guided by teaching and learning theories (see Lajoie & Azevedo, 2006). Essentially, the design process must be guided by teaching and learning theories, and evidence-based pedagogy and practices such as the "backward design" model (see Wiggins & McTighe, 2005) and the "constructive alignment" theory (see Biggs, 1999). Simply put, these are pedagogical approaches that start with the desired learning outcomes or end goal (e.g., what students must know and learn) rather than what content needs to be covered. Importantly, thoughtful considerations should be taken when designing blended courses, especially, in the context of instructional pedagogical design, implementations, and delivery modalities. Even, amid the madness of remote teaching, one can still design and implement a "remote blended learning" course varying in scope with emerging technologies while maintaining similar levels of interactive engagement and collaboration, for e.g., peer interaction and student-teacher interaction as in the case of the FTF context.

The established definition of blended learning is that it combines FTF and online instruction— a learning approach that takes place both on-campus and off-campus. Today we must rethink blended learning considerations in broader terms that can span to the context of remote teaching, that is, in terms of synchronous and asynchronous instruction or combining

FTF with synchronous and asynchronous instruction. In the Fall 2020 semester, I divided my remote course 50/50, that is, 50% of the time the entire course gathered online simultaneously for direct online instruction through MS Teams, and pre-recorded video lessons were posted online for the remaining 50%, with some degree of student control over time, place, or pace. The pre-recorded video lessons were posted online, and students had to perform these lessons within the allocated period (4-5 days) prior to the next class session. To ensure that students perform these pre-recorded lessons within the allocated period, for example, for every 3 lessons completed on time was considered as one assignment and incorporated as part of the overall course evaluations (ex. 3-5%). Furthermore, the overall course evaluation consists of the two-stage quizzes, web-based assignment with LON-CAPA, an online unit test, and one in-person midterm and standardized final exam. The performance in the standardized final exam was comparable to the Fall of 2017 performance, which was the last time this exam was administered. Moreover, the synchronous component of the course design included breakout rooms and learning communities that tend to facilitate more meaningful discussions, groupwork, collaboration, including peer instruction.

The course spans to 75 hours per semester (45 hours of lectures and 30 hours of laboratory periods), consists of two 1.5-hour lectures (3 hours/week), and one 2-hour laboratory session per week. The synchronous session of 1.5-hour long was divided into three parts: (a) a 30 minute interactive mini-lecture using MS PowerPoint via MS Teams, (b) a 30 minute problem solving component which included both conceptual and real-world examples, and (c) a 20 minute two-stage quiz where students get to work on the quiz individually for ten minutes, and then ten minutes were allocated to students where they could work together on the two-stage quiz with their peers in breakout rooms through MS Teams. The first stage of the quiz allows students to work independently, whereas the second stage allows students to co-construct and share their understanding and to providing each other with peer formative and corrective feedback. Students could change their answers after having a genuine discussion, demonstrated understanding, and the quizzes were then scanned and sent immediately as a pdf so they can be graded. Furthermore, the laboratory component was also delivered synchronously, where students get to conduct and collaborate on virtual labs with simulations, hands-on or home-labs using kits (or makeshift apparatus) in groups (3-4) via breakout rooms in MS Teams with the co-presence of the teacher. Each group (3-4) of students were able to follow the lab instruction, run the simulations, conduct the experiment, collect data, and then writing a final report.

Although online learning continues to evolve but there could be broader ways of cultivating blended learning to make it more transformative and wide-ranging, particularly, in the context of remote teaching. Today blended learning can span to include when and how to combine synchronous and asynchronous instructions using emerging technologies rather than when and how to combine FTF and online instruction or on-campus and off-campus instruction. Consequently, this new approach to blended learning can fundamentally un-hearth its true transformative potential and power in higher education. The lesson learned from the current pandemic will help educators improve, design, and implement more effective online or computer-mediated instructions, importantly, implementing more transformative approaches that are deemed indispensable and central to a more flexible, accommodating, and resilient education system. Nonetheless, this crisis presents researchers and educators a remarkable opportunity to change or rethink the higher education system to one that corresponds to the need of a new generation of learners and demographics and, subsequently, a greater opportunity to better plan for forthcoming disastrous events.

Concluding Remarks

This dissertation research sought to address some of the salient gaps in the research on blended learning and academic performance as topical efforts to unearth the relationships between blended learning and academic performance have yielded mixed or inconclusive findings. Referring to the research question: what is the link between blended learning and academic performance? By examining the overall findings of blended learning on students' learning outcomes compared to the traditional course, we found a strong positive effect of blended learning. In contrast, the overall finding in study 3 reveals a non-significant effect for a blended learning context which does not employ a conceptual framework or support for cognition. This blended context is less effective, that is, the learning outcome is comparable or equal to the traditional course. We discussed the results and offered implications for educational practice and research. Albeit the contributions of the dissertation, there is still much research that needs to be done apropos the effectiveness of blended learning on academic performance. The findings reported in the dissertation have broad implications for the blended learning literature, and that ongoing research leading to a better understanding of the relationship between blended learning and academic performance would be beneficial to both students and educators, practitioners, researchers, and university administrators.

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