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Research Article

The Effect of Blended Advanced Biotechnology Course Format on the Learning Process of Students in Engineering Technology Education

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Abstract

This study examines the efficacy of blended learning for engineering technology students, integrating the strengths of traditional in-person instruction with the flexibility and innovation facilitated by virtual learning platforms. It analyzes student responses associated with their learning outcomes in an in-person and blended learning environment within an undergraduate engineering technology program offered in a hybrid format, comprised of six weeks of in-person instruction and six weeks of blended learning. The findings demonstrate that students perceived blended learning as more advantageous, with increased engagement, enhanced learning and conceptual development, felt more actively involved in the learning process, and maintained higher levels of motivation to perform better in the course. These discoveries establish that blended learning is an effective educational approach for engineering technology students, cultivating improved academic outcomes and student satisfaction. The overall evaluation showed that 77% of students in blended learning expressed satisfaction, in contrast, 48% of students in an in-person learning environment shared similar sentiments. It was found that 73% of students agreed with blended learning contributing towards their enhanced learning experience. In comparison, 38% students agreed with the same statement, when in a traditional in-person learning environment. However, 68% and 62% of students, in blended and in-person classroom settings respectively agreed that they felt engaged through their corresponding delivery platforms. While 82% of students felt active in a blended learning environment, compared with 60% expressed the same for an in-person classroom environment.

Keywords

Biotechnology, Engineering Education, Blended Format, In-person Format

1. Introduction

We inhabit a world dependent on technology for nearly every aspect of our daily lives.

While “engineering” is the knowledge which is used to create these structures and materials, “engineering technology” is the field associated with the application and integration of these materials into our everyday routines. Although students in both programs study similar courses, the knowledge of engineers is found to be more theoretical based, whereas the education for engineering technology is further applied and associated with modern technology [1]. The rapid and modern

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technological advancements necessitate the need for technologists to analyze and improve products more efficiently than ever before. To keep up with the technological changes, engineers must be hyphenated [2], i.e., acquiring proficiency in multiple fields.

Biotechnology serves as a prime example of one such multidisciplinary program. The Biotechnology program offered at McMaster University combines the fields of basic and applied science with technology, to equip students with the skills and knowledge necessary to develop innovative solutions to real-world problems. The program also includes an accredited business management degree, enabling students to develop the soft skills necessary to effectively communicate their ideas in a professional industry setting. Biotechnology consists of a wide variety of modern branches including pharmaceutical manufacturing, clinical research, genetic engineering, microbiology, agricultural biotechnology, healthcare [3], biofuels, bioinformatics, and business management.

The Biotechnology program at McMaster University presents a unique hands-on experience, requiring undergraduate students to complete over 700 hours in a laboratory environment before graduation. Each course in the program is structured with classes occurring typically twice a week: with one session dedicated to a traditional lecture and the second to either a laboratory class or pedagogical-based learning practices [4-7], allowing students to directly apply the knowledge gained in the lecture. However, due to the coronavirus pandemic, the course delivery structure was modified, with thousands of other educational institutions also transferring to an online learning environment.

Prior to the pandemic, majority of instructors favoured traditional teaching practices and were hesitant to incorporate technology into their teaching due to their lack of experience with virtual tools [8]. Distractions, leading to lack of focus, the possibility of cheating, and concerns about the reliability of resources are additional reasons that contribute to the reluctancy in using technology in classrooms. Opposingly, teachers who valued its importance would only permit the use of technology for pre-reading lectures online before coming to class or for using search engines to gain deeper insights into the topic. Therefore, instead of being reliant on technology, it was merely used as a supplementary tool to assist in teaching [9] prior to the pandemic.

During the pandemic, thousands of institutions had no choice but to implement online learning platforms to deliver lessons online. Research establishes [10-13] that well-designed digital platforms were able to augment student learning, motivation, and satisfaction. One such popular platform is Zoom, due to its high-quality audio and video connectivity, and ability to monitor classroom attendance with ease, culminating in exemplary time management from students [14, 15]. This platform also enables students and teachers to facilitate personalized interactions via private chat boxes, particularly beneficial for introverted individuals. It also supports group discussions and provides an equal opportunity for all students to participate. Rahayu's study [16] exhibits that majority students expressed being able to communicate more comfortably during group discussions using Zoom.

In a recent study conducted among engineering technology students at McMaster University [7], comparing virtual and in-person education, it was observed that students became highly accustomed to the virtual learning environment during the pandemic. As a result, they found it difficult to adjust back to an in-person classroom and regain the confidence to express themselves freely. This implies that the ingrained comfortability with the virtual learning environment resulted in the students becoming accustomed to interacting through computer screens, documenting answers with online tools, and avoiding the dynamics of face-to-face group discussions and real-time interactions [7]. This has prompted educational institutions to question which delivery platform truly serves students the best.

Discovering effective strategies to best integrate digital technologies into traditional classroom settings is referred to as course modalities in the education sector [17]. The use of digital technologies in classrooms and converting in-person learning into blended learning has been defined as the prime objective of contemporary digital transformation in education [18]. Several studies [19-22] demonstrate that students achieved equal levels of improvement in both, knowledge and skills in a virtual classroom setting, when compared with the traditional in-person learning environment. Subsequently, blended learning approaches have resulted in further enhancement of these skills [23-26].

Forde and colleagues [27] guided a study comparing in-person, blended, and online teaching approaches, revealing statistically significant differences in the skill competency levels amongst the three groups. The online learning group achieved a 17% competency level, whereas the in-person group attained 75%. The blended learning group with 89%, demonstrated the highest confidence in their knowledge and aptitude to apply skills in a clinical environment. Sala et al. [28] conducted a systematic literature review examining the adoption of blended learning in engineering, the impact of COVID-19 on this transition, and its application across different levels of Bloom's taxonomy.

The implementation of blended learning provides students the opportunity to integrate different forms of online learning methods in a traditional classroom environment, effectively bridging the gap between physical and virtual classrooms [29]. Blended learning has been increasingly popular post pandemic due to its flexibility, allowing students more time to analyze and solve complex problems, conduct extensive research, and experience reduced stress and pressure compared with a traditional in-person learning environment. The online resources also complement in-person learning, fostering opportunities for self-directed learning beyond the perimeters of a classroom [30, 31].

2. Methodology

The study involves students enrolled in the Advanced Biotechnology course (BIOTECH 4TB3), a fourth-year undergraduate biotechnology course at McMaster University. This advanced course explores topics of relevance, reflecting existing methods used to develop new products and practices in the field of biotechnology. Assessment methods include case studies, weekly quizzes, a mid-term test, project presentation, class participation, attending guest speaker presentations, and a comprehensive final exam.

The course includes three weekly lectures, one hour and two hours long. In Fall 2023, the course was redesigned to offer a blended learning platform post-pandemic, featuring six weeks of in-person learning and six weeks of blended learning i.e., one hour in a virtual based and two hours in an in-person classroom setting. The students were asked to complete an anonymous survey to express their opinions on both, in-person and blended delivery formats. Forty three students participated in this survey study; the survey comprised of 10 questions associated with the perceptions of the students on the learning outcomes for both delivery formats. The students rated their responses on a scale of 1-5 wherein: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. The methodology for the learning process survey was adapted with modifications from Garcia et al. [32].

3. Results and Discussion

3.1. Student Frustration

Frustration is perceived as a negative emotion that students might experience when faced with unforeseen cognitive challenges, often arising when there is an obstruction in the path towards achieving their set academic goals [33, 34]. Consequently, the method of classroom delivery, whether in-person or blended, can significantly contribute to student frustration. Figure 1 depicts 6.9% of students having experienced frustration in a blended learning environment, whereas 19.1% students experienced the same in an in-person learning environment. This observation is highly contrasting to other studies reported [35-37], wherein students felt more frustrated in a digital environment due to lack of engagement and technical hindrances.

In this case, students might have felt more frustrated in the in-person classroom setting after having acclimatized to the virtual or blended course environment post-pandemic. Social pressures, classroom noise, and challenges in maintaining decorum can all lead to student frustration. Additionally, the lack of individual attention from the teacher can cause some students to feel neglected, heightening their frustration, especially if they are already struggling in understanding the course material.

Figure 1. The effect of blended and in-person learning on student frustration.

3.2. Student Activity

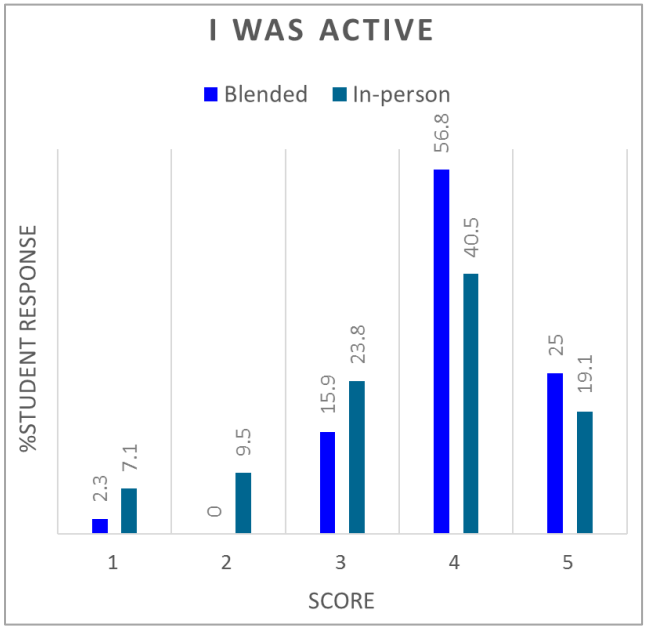

Figure 2. The effect of blended and in-person learning on students feeling active.

Blended learning has been recognized [38-41] to promote active student engagement through improved student-teacher communication by utilizing interactive virtual platforms. Figure 2 exhibits that majority, i.e., approximately 82% of students reported feeling active in a blended learning environment, while 60% expressed the same for an in-person

classroom environment. The high percentages indicate that students felt active during both delivery formats. However, a greater number of students reported feeling active during blended learning due to the integration of technology and engaging materials which have the ability to accommodate diverse learning preferences, and the flexibility which comes with it. The combination of traditional classroom benefits with the flexibility of online learning creates the ideal blended environment to foster active student involvement.

3.3. Student Motivation

As a result, the impact of blended and in-person learning on student motivation, illustrated in Figure 3, demonstrates similar findings to Figure 2. The graph portrays that 71% of students in blended learning environments and 50% of students in in-person learning environments agreed that their respective delivery formats motivated them in class.

Acknowledging the learning needs of students plays a significant role in motivating students to participate actively [41]. The state of feeling active and motivated are interconnected in a learning environment. When students feel active, it encourages them to participate more in class, cultivating a stronger connection with the learning process, ultimately enhancing their overall motivation. Likewise, motivated students are more inclined to actively engage in classroom discussions and ask questions, leading to an improved learning experience.

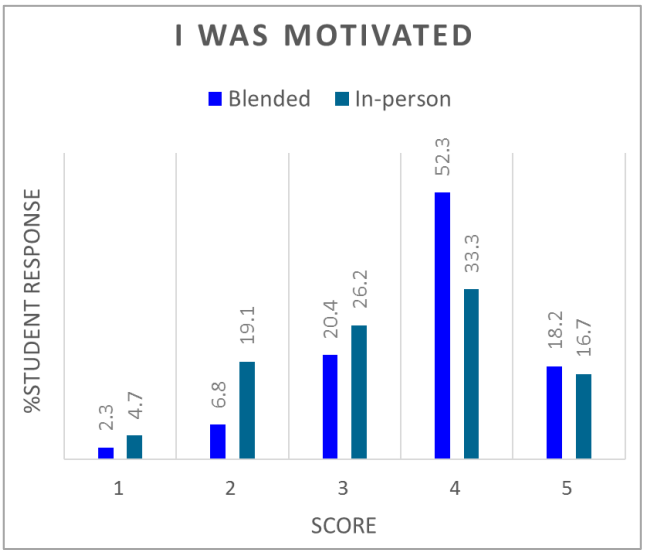

Figure 3. *The effect of blended and in-person learning on students feeling motivated.*

3.4. Feeling Challenged

The state of feeling challenged often stems from the perceived difficulty level of the course. As displayed in Figure 4, an equal proportion of students (i.e., 50%) expressed neutrality when asked if they felt challenged in the course, irrespective of whether the learning environment was blended or in-person. Given the difficulty level established at the beginning of the course, students might have approached both environments with similar expectations. This neutrality suggests that students found the difficulty level of the course in both learning environments to be consistent and manageable. Furthermore, this also establishes that the educational institution was successful in providing a fair and consistent learning experience across both delivery platforms.

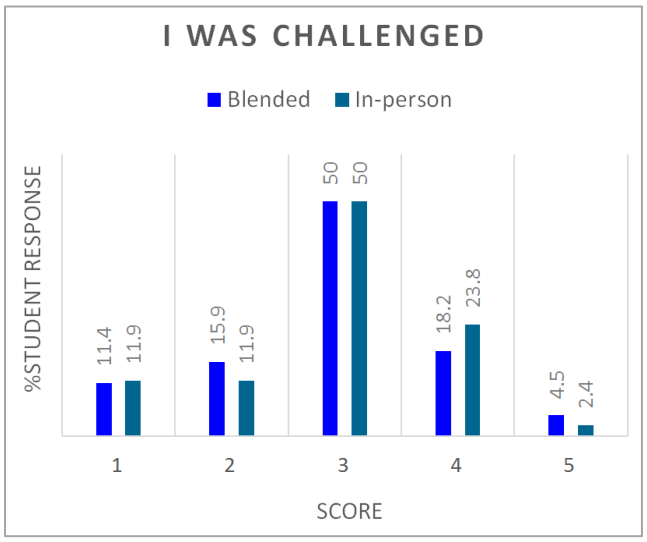

Figure 4. *The effect of blended and in-person learning on students feeling challenged.*

3.5. Student Engagement

A total of 68.2% and 61.9% of students, in blended and in-person classroom settings respectively, agreed that they felt engaged through their corresponding delivery platforms (Figure 5). The slight variation in the percentages may be attributed to the combination of online and face-to-face interactions in blended learning, accommodating different learning styles while keeping the learning experience dynamic, and minimizing monotony. The assortment of resources in a blended environment can support student engagement more effectively than a single mode of delivery.

Blended learning methods and student engagement are known to be closely related [42, 43] The prime reason for the increasing popularity of blended learning is its ability to enrich student engagement [44]. Furthermore, the two fundamental divisions of engagement, emotional and cognitive, have been identified to be imperative to blended learning. Huang and colleagues [43] outline logical pedagogical suggestions for the development of optimized activities in blended learning courses to attain increased levels of student engagement.

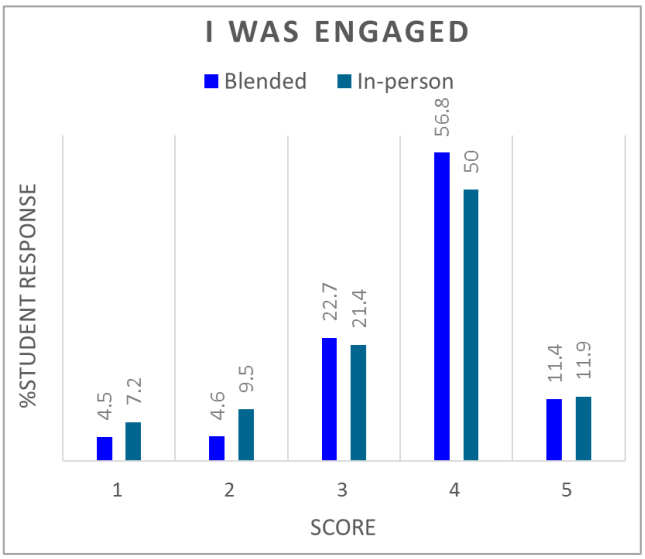

Figure 5. *The effect of blended and in-person learning on student engagement.*

3.6. Student Confusion

The rise in adoption of blended and digital learning environments necessitates rapid intervention when students experience confusion. Kennedy and Lodge [45] define confusion as a significant barrier in the learning process. According to Dweck [46], confusion is commonly observed in students with prior lower academic performance and reduced self-confidence. Students may perceive their confusion as their inability to comprehend material, affecting their learning experience adversely. Therefore, overcoming confusion is vital in enhancing student learning [47].

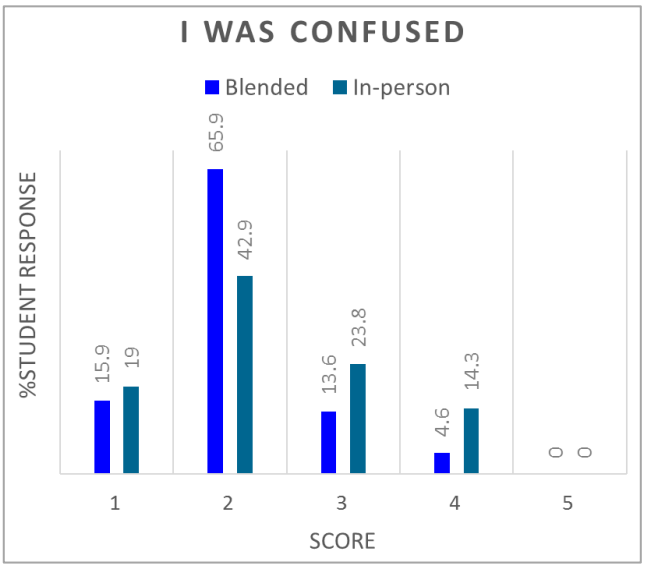

Figure 6. *The effect of blended and in-person learning on student confusion.*

Empirical evidence presented in Figure 6 shows that students in an in-person learning environment experienced higher levels of confusion (14.3%), compared to those in blended settings (4.6%). This discrepancy can be attributed to the flexibility of reviewing recorded lectures at any time, the diversity of resources offered, and receiving immediate clarification and feedback via the use of digital tools in blended learning. To mitigate confusion in in-person settings, instructors can implement strategies such as providing access to supplementary academic resources online, adopting active learning techniques, and providing office hours for students requiring additional help.

3.7. Understanding of Concepts

Developing a better understanding of concepts is highly dependent on factors such as clarity of instruction, engagement, active learning, relevance and context, a positive and healthy learning environment, timely feedback on assessments, and the ability to self-reflect on concepts taught in class. As reported in Figure 7, students reported a significantly higher understanding of concepts in blended learning environments (77.3%) compared to in-person settings (54.7%). A higher level of understanding is prevalent in blended learners, largely attributed to the key advantage of blended learning i.e., keeping students engaged beyond traditional classroom. When students have the flexibility to study at their own pace outside the classroom, they gain additional time to delve into topics of interest and conduct in-depth research. This self-directed exploration contributes significantly to their improved understanding of concepts.

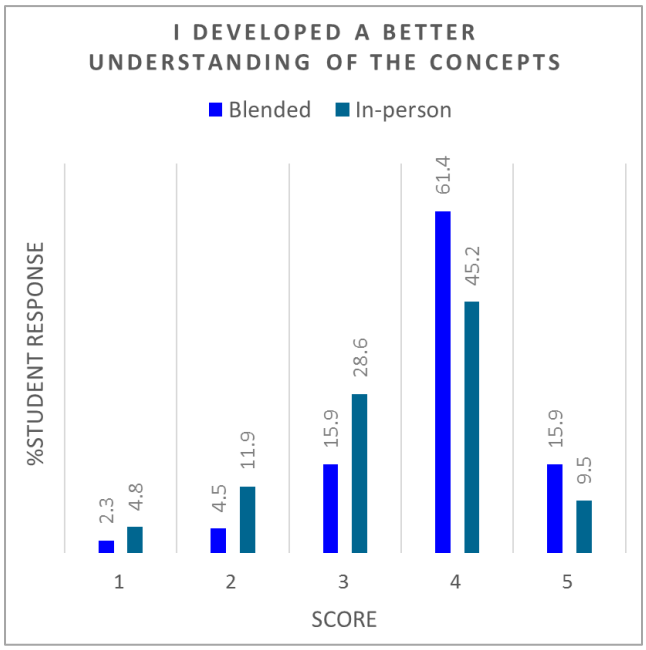

Figure 7. *The effect of blended and in-person learning on helping students develop a better understanding of the concepts.*

3.8. Need for Additional Guidance

Collectively, 70.5% of students in blended and 52.4% in an in-person classroom setting, either strongly disagreed or simply disagreed requiring the need for additional guidance from the instructor (Figure 8). This can be explained due to the existence of common factors relevant in both modes of delivery including complexity of subject matter, student confidence and prior knowledge, learning impasses, and the effectiveness of instructor delivery.

On the other hand, 11.9% students in an in-person learning environment voiced the need for more guidance from the instructor, due to the lack of individual attention provided in a traditional classroom setting. As the traditional lecture session concludes, both students and teachers often hurriedly rush to other classes and commitments, leaving minimal time and space to reflect on the content studied. Hence, the limited availability of interaction opportunities significantly influences the effectiveness of the learning experience, compelling the need for additional assistance. In contrast, the blended learning approach facilitates enhanced communication between teachers and students outside of the classroom using virtual platforms, allowing for more extensive interaction.

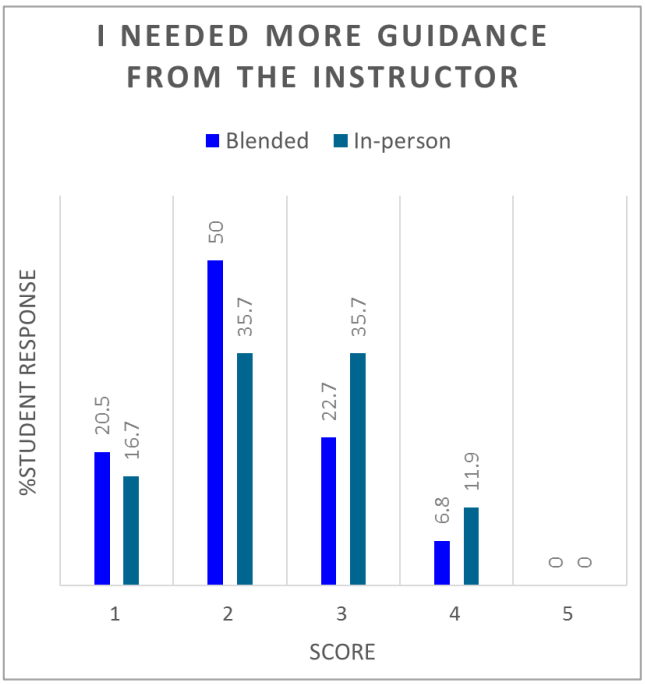

Figure 8. *The effect of blended and in-person learning on the need for students to require more guidance from the instructor.*

3.9. Student Learning

Each student possesses a unique learning style, with some preferring the traditional in-person auditory lecture or self-paced reading post-lecture, while others find learning from a combination of methods most beneficial. Blended learning is an approach which accommodates this diversity by offering access to various resources, including in-person sessions, live lectures, recorded content, and online materials. This approach fosters a personalized learning experience where students are able to study at their own pace and revisit material as needed, promoting a conducive learning environment. The flexibility inherent in blended learning supports deeper comprehension of the subject matter, enhancing overall learning outcomes.

Figure 9 illustrates that 59.1% of students agreed and 13.6% students strongly agreed with blended learning contributing towards their enhanced learning experience. In comparison, 30.9% students agreed and 7.2% strongly agreed with the same statement, when in a traditional in-person learning environment. The observed disparity between these two delivery methods in terms of their impact on student learning can be attributed to the factors discussed above. This finding aligns with the conclusions drawn by [48-50] in their research on educational methodologies.

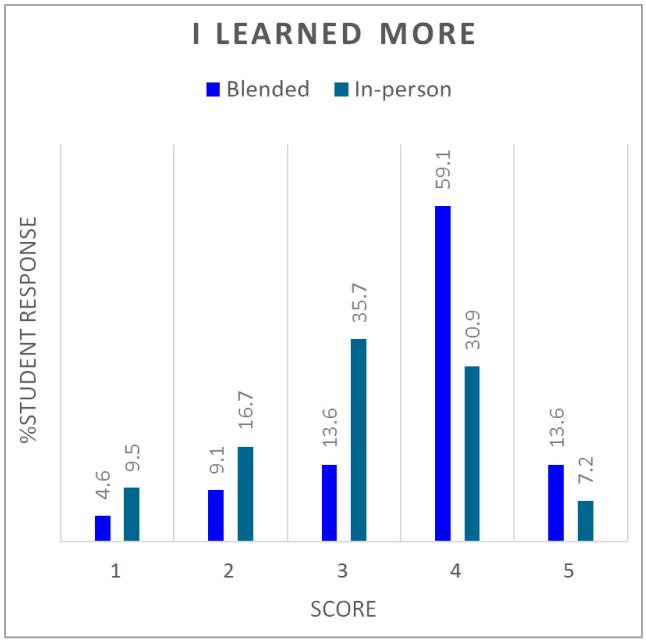

Figure 9. *The effect of blended and in-person learning in helping students learn more.*

3.10. Overall Evaluation

Finally, when comparing the overall student course satisfaction between blended and in-person learning environments, a combined 77.3% of students in blended learning (40.9% agreed and 36.4% strongly agreed) expressed satisfaction. In contrast, 47.7% of students in an in-person learning environment (28.6% agreed and 19.1% strongly agreed) shared similar sentiments. The higher satisfaction in blended learning can be associated with increased activity, motivation, en-

gagement, better understanding of concepts, and enhanced learning outcomes discussed earlier. Several studies [51-53] have also reported the adoption of blended learning leading to increased academic achievement for students.

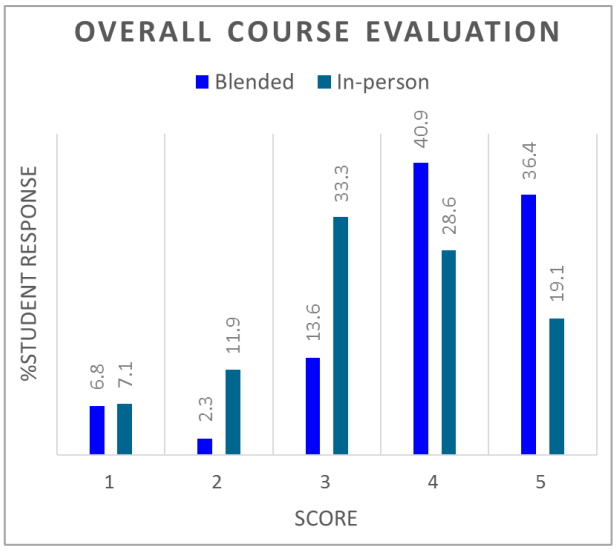

Figure 10. *The effect of blended and in-person learning on the overall course evaluation.*

While these results may be subject to bias as student responses could be influenced by the specific course being taught rather than the mode of delivery, the results from the preceding opinions of students discussed demonstrate that the blended learning approach has the ability to promote more effective learning outcomes. This is achieved through the utilization of technological resources and the accommodation of diverse learning preferences and needs.

4. Conclusions

The concept of blended learning transcends beyond the simplistic notion of merely combining in-person instruction with remote learning. It includes the strategic integration of traditional in-person teaching and digital resources, aimed at personalizing the learning experience of students. The most significant challenge presented by this approach is its very integration into the existing teaching and learning framework. To address this effectively, robust technology support and appropriate infrastructure are essential.

Table 1 presents a comprehensive summary of student feedback regarding the impact of blended and in-person settings on their learning outcomes, denoted by ↑ = indicating a higher effect, and ↓ = indicating a lower effect induced by the delivery format on the attribute in question. The empirical evidence from this study highlights and corroborates the major advantages of blended learning on student learning outcomes, over traditional in-person instruction.

Table 1. *Overall summary of student opinions on the effect of blended and in-person settings on their learning outcomes, with ↑ = higher effect, and ↓ = lower effect.*

	Blended Learning	In-person Learning
I was frustrated	↓	↑
I was active	↑	↓
I felt motivated	↑	↓
I was challenged	↓	↑
I was engaged	↑	↓
I was confused	↓	↑
I developed a better understanding of concepts	↑	↓
I needed more guidance from the instructor	↓	↑
I learned more	↑	↓
Overall course evaluation	↑	↓

Blended learning accommodates various learning styles by providing multiple modalities, including visual, auditory, and kinesthetic approaches, and allows students to access lectures, resources, and assignments online, offering flexibility in balancing their study schedules. Engineering technology students benefit significantly from the diverse resources available through blended learning, such as simulations, virtual labs, and multimedia content, which enhance their grasp of complex engineering principles. The online resources also act as a supplement to in-class learning, thereby promoting opportunities

for self-regulated learning behavior outside of class.

Furthermore, blended learning can incorporate industry-standard software and tools into online modules, equipping students with practical skills relevant to their future careers. The future of blended learning is driven by technological advancements and changing educational needs. Therefore, this approach will require continuous innovation and adaptation by educators, institutions, and policymakers to fully realize its potential.

Author Contributions

Faiez Alani: Investigation, Project administration, Supervision, Writing – review & editing

Rehmat Grewal: Conceptualization, Formal Analysis, Methodology, Writing – original draft

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Data Availability Statement

The data is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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