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Virtual versus In-Person Case-Based Learning for Lower Year Courses in Engineering Technology Education

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Abstract

The coronavirus (COVID-19) global pandemic resulted in shifting student learning from an in-person format to an online-based learning environment to ensure the safety of both students and staff. As the government-imposed lockdowns are lifted with the pandemic coming to an end, institutions evaluate whether to continue providing a virtual e-based learning or offer a hybrid learning platform for courses. Thus, this suggests the need to evaluate the effectiveness of online learning as compared to in-person learning, and even more so, how the format of delivery affects active learning strategies including case-based learning (CBL). This study compares the effectiveness of online CBL and in-person CBL in two different undergraduate engineering technology courses offered at McMaster University. The two courses were initially conducted virtually but were switched to the in-person format in the middle of the semester with the university having re-opened, providing the students with a better distinction between the two formats. At the end of the semester, the students in both courses were asked to provide their perceptions on the effect of CBL on their analytical skills (critical thinking and problem-solving), interpersonal skills (communication and teamwork), real-life technical skills, learning experience, self-confidence and performance, and deeper conceptual understanding via an anonymous survey. The survey results demonstrated a high positive response for the in-person CBL, whereas the virtual CBL included varying responses throughout the five-point grading scale. The results obtained from the survey imply that students were more perceptive of the positive effects of the in-person CBL, compared to the virtual CBL. Furthermore, the responses were similar for the two different courses, complying with the trend of favouring the face-to-face CBL format.

Keywords

Engineering Education, Case-Based Learning, Case Study, Biotechnology

1. Introduction

Various disciplines in higher education have begun implementing the use of active learning methods over the conventional lecture-based learning. Active learning modalities including problem-based learning, case-based-learning, and flipped learning have been integrated; with active participation and student engagement being the prime components of these methods (Borte et al., 2020; Rodríguez et al., 2018). This study focuses on case-based learning (CBL) which is one of the strategies that uses real-life case studies to help deepen student learning and application of knowledge through team interactions and discussions. Multiple studies have shown that CBL has helped in increasing student motivation and course performance, in addition to student learning and understanding. A study conducted by Kazeruni et al. (2018), found that students in a hybrid lecture and case-based engineering course were able to enhance their learning via the adoption of CBL. Another study with nursing students found that CBL was effective in increasing problem-solving skills and the learning motivation of the nursing students (Gholami et al., 2021). In addition, McLean (2016) examined the effect of case-based learning in the medical and healthcare industry to conclude that CBL can influence teamwork, clinical skills, as well as behaviour. This is essential as the ever-changing workforce environment constantly requires graduate students to be creative and flexible in applying their knowledge from theory to practice to remain competitive in the market.

With that said, the advent of the COVID-19 pandemic impelled educational institutions to adapt to online learning with the need to protect the health and safety of the students, faculty, and staff, and prevent the further spread of the virus. The use of online learning and distance education has been continuously increasing in higher education, even prior to the pandemic. Online learning is also referred to as virtual learning, eLearning, distance learning, or web-based learning, which could either be synchronous or asynchronous (Means et al., 2014). While these terms have different connotations and methodologies, "online learning" and "virtual learning" is used interchangeably in this paper and refers to a synchronous videoconferencing platform with the instructor and the students. As education moves towards online learning environments, the effectiveness of online learning is questioned. In a study by Kim et al. (2012) and Mital (2012), it was found that learning motivation and face-to-face interactions had a significant impact on the learner's satisfaction which would in turn affect their performance, in addition to other factors like ease of use and usefulness of the content. Similarly, many other challenges/factors revolving around online learning could affect student motivation and learning experience, resulting in affecting their overall learning gains (Song et al., 2004). Furthermore, in a systematic review reported by Pei & Wu (2019), the authors present that while online learning was comparable to face-to-face learning, corroborating online-learning being effective compared to in-person learning has yet to be confirmed. Additionally, it was presented that the effectiveness of online learning was varied. These conclusions are essential since the translation of student-centered active

learning instructional modes like CBL might yield different results in effectiveness due to different learner requirements such as more direct instruction and more interaction between peers and the instructor to be effective (Cho et al., 2015). Hence, the need to analyze the effectiveness of CBL in an online format as compared to the traditional in-person format.

In a previous study where face-to-face CBL was conducted, it was found that CBL was effective in improving the overall performance of the students in the course by enhancing their learning experience, self-confidence, and conceptual and deeper understanding in comparison to traditional lecture-based learning (Alani et al., 2022). Thus, the primary aim of this study was to compare the effectiveness of CBL based on the two methods of delivery, online/virtual or in-person. This was done by analyzing the perceptions of students on the effects of CBL on their critical thinking, problem-solving, teamwork, communications skills, real-life technical skills, self-confidence, performance, conceptual understanding and application, and deeper understanding. This comparison between formats would benefit in answering questions associated with which format of CBL was chosen by the students to be more effective in improving their overall learning outcomes and experience. Moreover, the comparison of these two methods of delivery would be beneficial in not only the future development of CBL courses, but also in the implementation and integration of CBL in engineering technology courses.

2. Methodology

2.1. Study Context

This paper investigates the in-person and virtual format of delivery of the inquiry-based active learning modality, CBL. This study was conducted on students pursuing two different second year undergraduate engineering technology courses offered, "Biotechnology Concepts" and "Microbiology," both of which were offered simultaneously during the winter semester of 2022. Both courses used a method that alternated between lecture-based teaching and case-based active learning. Each course comprised of 30 students, all of which took both courses concurrently.

The COVID-19 pandemic led to the closure of in-person classes at universities during the end of the Winter 2020 semester and hence, both courses were adapted to an online format. Soon after, during the Winter 2022 semester, the government-imposed restrictions were gradually lifted, resulting in universities to re-open and for the students to go back to the classrooms. This caused a shift from an online setting to an in-person classroom setting within the same semester, allowing students to distinctly compare between the two instructional formats.

2.2. Virtual CBL Format

Both courses acclimated to online learning supported by a real-time videoconfe-

rence with the instructor, using the videotelephony software Zoom. Hence, both the lecture and active learning components of the course were performed using this platform. The classes operated similarly to how the in-person classes worked prior to the switch online, where the teaching was directed through lectures and the active learning components of the course was carried out in groups. Zoom served as an extremely beneficial platform for this purpose since it is capable of opening multiple videoconference rooms simultaneously, called "breakout" rooms. In these breakout rooms, students could communicate with their peers either through the chat option or by audio (microphone) and were also able to share their screens to facilitate collaborating. In addition, within the rooms, the students have access to the professor should they need assistance during the session. Likewise, the instructor was also able to enter the rooms to see how the students were doing during the session.

For the active learning sessions, the students were randomly assigned breakout rooms to form groups of three. The case studies were made available to the students through the university's Learning Management System (LMS) at the beginning of the session. Once the session ended, the students were required to submit one copy of their solutions for grading.

2.3. In-Person CBL Format

The format of the in-person CBL was like the virtual format wherein groups of three students were formed to solve the case study. The case study was made available for the teams to access in LMS at the beginning of the active learning session. Similarly, the groups would then submit a copy of their solution for grading at the end of the class.

2.4. Data Sources

At the end of the semester, an anonymous survey using a five-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree) was used to record the perceptions of students on the effects of CBL, and to compare between the virtual and in-person formats of case studies. The survey consisted of a total of 10 statements which the students were required to evaluate by selecting their level of agreement/disagreement on the statement, including an overall evaluation of CBL (Alani et al., 2022). The statement topics revolved around whether CBL, both virtual and in-person, had a positive effect on the students' personal skills (critical thinking, problem solving, teamwork, communication, and real-life technical skills), performance and self-confidence, learning experience, and course knowledge (concept understanding and application, and deeper understanding).

2.5. Case Studies

The switch from virtual to in-person learning occurred after having performed a total of 3 case studies virtually during the beginning of the semester, resulting in

completing the remaining 7 case studies in-person. Both courses, Biotechnology Concepts and Microbiology included weekly case studies, except for the first and last weeks of the term, forming a total of 10 case studies for each course. The topic of the case study was associated with the topic being taught in the course at that week. For example, in the course Biotechnology Concepts, the case called "Jute gene tweak boost yields and fiber quality" was studied, which was derived from the topic of Recombinant DNA Technology. For the Microbiology course, an example of a case study for the topic of epidemiology was investigated, called "Patient Zero: The Origins, Risks, and Prevention of Emerging Diseases."

3. Results and Discussion

The results demonstrate that the format in which the case studies were delivered caused the students to have different opinions on the effects of CBL. In general, the in-person case studies had a higher positive evaluation from the students, while the virtual case studies had varying responses within the five-point scale. Although both courses consisted of students varying in undergraduate program level and associated course content, the survey yielded similar results for both courses.

3.1. Higher-Order Thinking Skills: Critical Thinking and Problem-Solving

Critical thinking and problem-solving were the two parameters categorized under higher-order thinking skills which provided similar results for both courses. As illustrated in **Figure 1** and **Figure 2**, most of the students agreed or strongly agreed that in-person CBL helped improve their critical thinking (Biotechnology Concepts (BC): 75%, Microbiology (M): 88%) and problem-solving (BC: 92%, M: 81%). Similarly, most of the students also agreed or strongly agreed that virtual CBL helped enhance their critical thinking (BC: 60%, M: 50%) and problem-solving skills (BC: 53%, M: 50%). These results abide with previous studies where it was demonstrated that CBL helped increase the students' higher order thinking which includes critical thinking and problem-solving skills (Menezes et al., 2021, Li et al., 2019, Miri et al., 2007, Garcia et al., 2012). From these results, it is evident that although the virtual CBL had a lower positive response compared to the in-person CBL format, the students still perceived that CBL did indeed helped their thinking skills.

Some reasons as to why virtual CBL had a lower positive response compared to in-person CBL has to do with the online environment itself, and how the students worked during the active learning session. In CBL, discussion and interaction within the team is crucial to evoke deeper conversations and instigate more brainstorming amongst the students about the case (Menezes et al., 2021, Garcia et al., 2012). This is relevant as some studies found that technical difficulties were one of the challenges faced when implementing online learning, which could cause difficulties with communication (Song et al., 2004, Nicklen et al., 2016).

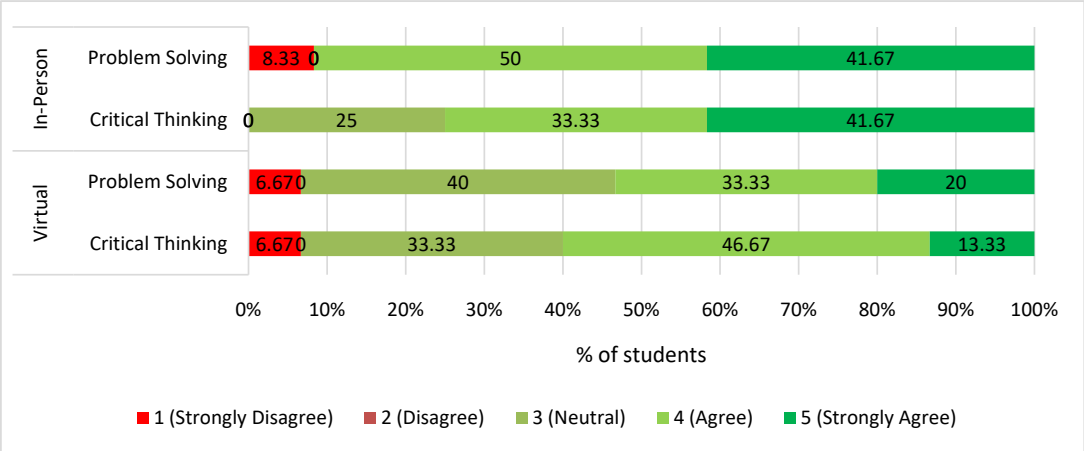

Figure 1. The effect of CBL on higher-order thinking for students in the course Biotechnology Concepts.

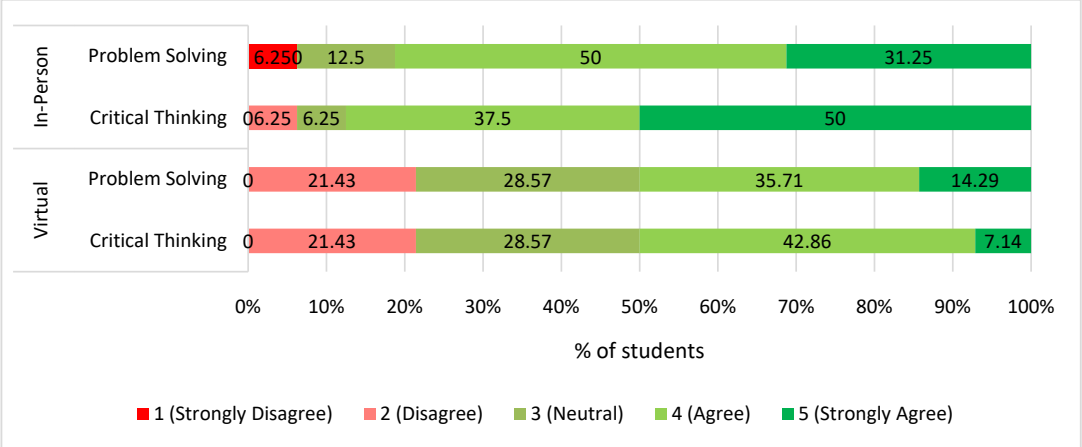

Figure 2. The effect of CBL on higher-order thinking for students in the course Microbiology.

During an active learning session, technical problems (e.g., choppy audio, disconnecting due to slow internet connection, etc.) are very interruptive to the discussions and could cause the students to discuss less or even end the discussion prematurely. Opposingly, for the case studies conducted in-person, these difficulties are not present and hence, it allows the students to have broader and more meaningful discussions pertaining to the topic on hand.

Another aspect that could influence the critical thinking and problem-solving skills of students in virtual CBL is that students tend to divide and assign the case questions to each member of the group rather than going through each question as a group. Hence, the group discussions are limited as each student could just complete their own questions without discussing. Besides, virtual CBL facilitates this since students can just divide and assign the questions, talk about the shared document and where to input their solutions, and completely mute themselves for the duration of the active learning session. This is indifferent to face-to-face CBL, where the students can see each other face-to-face and cohesively solve their questions. In addition, some teams in the face-to-face CBL answer the case questions one by one as a group, questioning their ideas and solu-

tions with each other before finalizing their answers. Overall, these are some factors that can potentially contribute to the differences between the effects of virtual and in-person CBL on the students' critical thinking and problem-solving skills.

3.2. Interpersonal Skills: Teamwork and Communication Skills

This leads to teamwork and communication skills, classified under interpersonal skills, both of which were also analyzed in this study. As demonstrated in Figure 3 and Figure 4, most of the students agreed or strongly agreed that in-person CBL helped improve their teamwork (BC: 92%, M: 69%) and communication skills (BC: 92%, M: 69%). On the other hand, the responses from the virtual case studies varied with most students having a neutral perception on the effects of CBL for both skills (teamwork: 47%, communication: 53%) in the course Biotechnology Concepts, and for teamwork (50%) in the Microbiology course. Meanwhile, majority of the students disagreed or strongly disagreed (64%) for CBL having improved their communication skills in the Microbiology course.

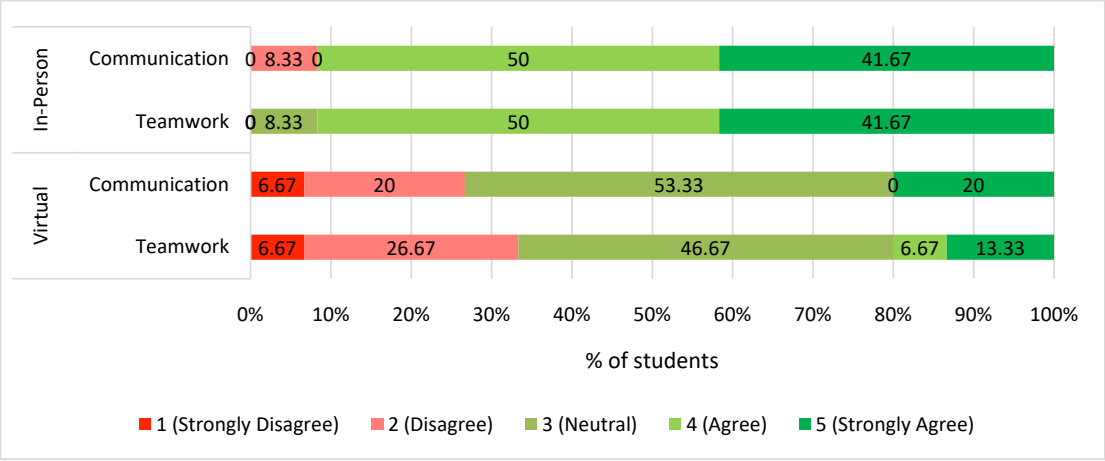

Figure 3. The effect of CBL on interpersonal skills for students in the course Biotechnology Concepts.

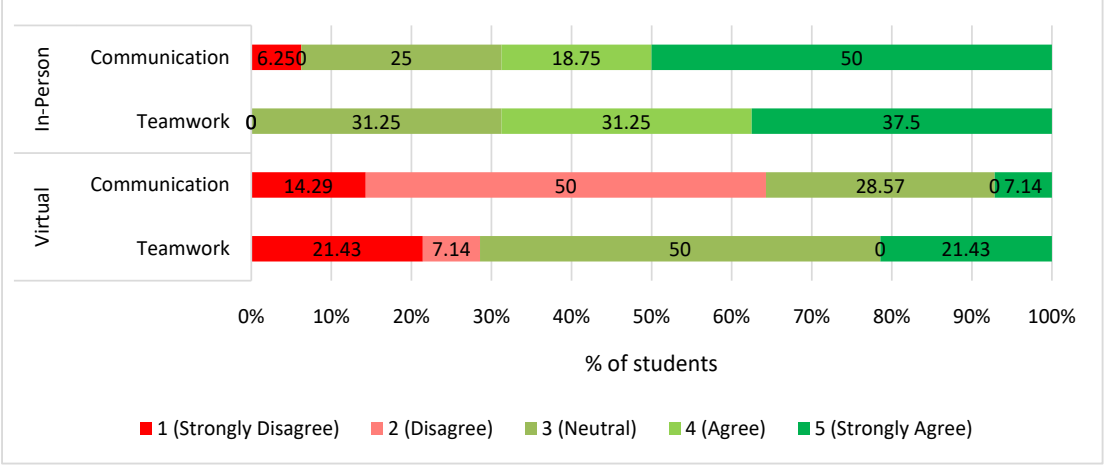

Figure 4. The effect of CBL on interpersonal skills for students in the course Microbiology.

These results illustrate that the students believed that in-person case studies helped improve their teamwork and communication skills, while virtual case studies had no effect or possibly even a negative effect on these skills. These results correspond to a study where it was found that face-to-face meetings aided in training the communication skills of students more compared to virtual discussions (Raupach et al., 2009). Although a synchronous virtual environment mimics the face-to-face interactions, technical problems in online environments could cause difficulties in communication by hindering discussions which is an important component of CBL (Rodríguez et al., 2018, Song et al., 2004, Miri et al., 2007). This is important as it is one of the possible reasons as to why students would be less inclined to participate which would in turn, affect the experience and the teamwork of the group. Moreover, for this study, the students were grouped randomly for the case of virtual CBL which is another challenge. Along with the addition of possible communication complications, the positive results were lower, and the students were not able to perceive the full extent of the intended benefits of CBL in the virtual mode. The in-person CBL, on the other hand, received positive results for both teamwork and communication skills in both courses which could be attributed to less communication difficulties. Furthermore, in face-to-face settings, the groups are usually formed depending on the seating, in other words, the people seated close to them which are usually peers they already know within the class. This makes it easier for the students to be comfortable to ask questions or voice their opinions within the group. Nonetheless, the students perceived CBL to have induced more positive effects to their communication and teamwork skills for the in-person CBL compared to the virtual CBL.

3.3. Real-Life Technical Skills

In addition to encouraging interactions and discussions within the class, CBL is known to help bridge the knowledge gap between class and real-life practice in the industry (Miri et al., 2007, Garcia et al., 2012). Aside from the higher order thinking skills and the interpersonal skills, the effects of CBL on the real-life technical skills of students were also investigated. As seen in **Figure 5** and **Figure 6**, most students agreed or strongly agreed to the effects of in-person CBL on their real-life technical skills for both the Biotechnology Concepts (83%) and Microbiology (56%) course. Whereas for the virtual CBL, most of the students had neutral perceptions on the effects of CBL for both courses (BC: 47%, M: 43%). This signifies that the students agreed that in-person CBL positively affected their real-life technical skills, while virtual CBL had no effects. This difference could be due to the circumstances during the study since the virtual format was conducted at the beginning of the semester where most topics taught were introductory and were the foundations of the course. Whereas the in-person format, which was provided during the mid to the end time frame of the course, the students were already taught the basics and were already familiar

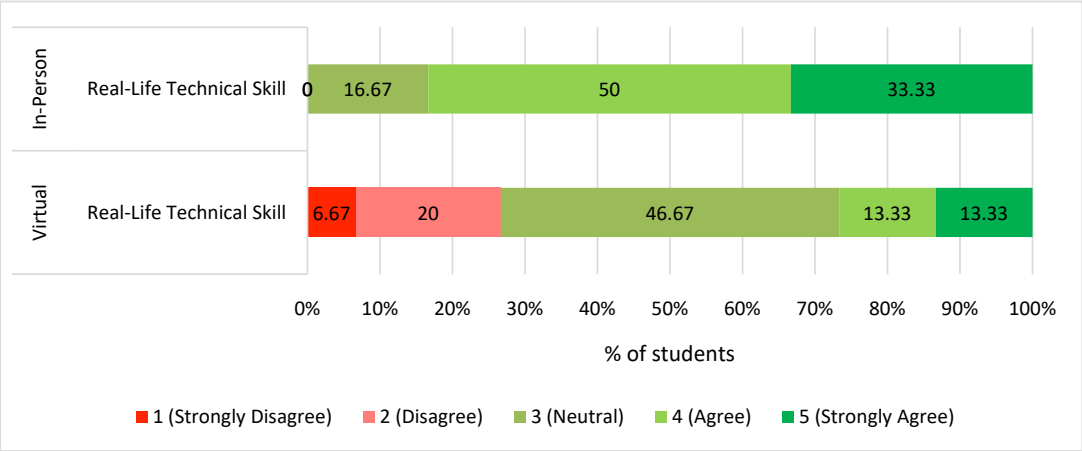

Figure 5. The effect of CBL on the real-life technical skills of students in the course Biotechnology Concepts.

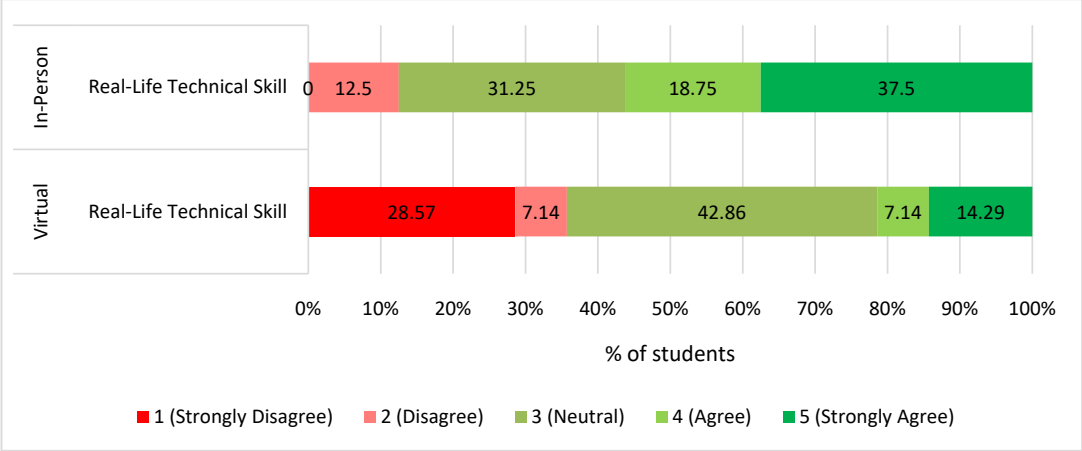

Figure 6. The effect of CBL on the real-life technical skills of students in the course Microbiology.

with how case studies were performed within the course. This is important since CBL was deemed more effective if students already possessed prior knowledge of the content and required recalling and applying it to solve the case (McLean, 2016, Menezes et al., 2021). In other words, the students would have been able to use the knowledge they have to solve a real-life scenario and brainstorm their solutions with each other easier when retaining the background knowledge. These findings insinuate that further studies are required to better compare the effects of virtual or in-person CBL on the real-life technical skills of students.

3.4. Performance and Self-Confidence

The perception of students on the effects of case studies on their performance and self-confidence were other parameters examined in this study. The associated results are depicted in **Figure 7** and **Figure 8**. The results show that for both courses the students agreed or strongly agreed that in-person CBL had a positive effect on their performance (Biotechnology concepts: 83%, Microbiology: 94%) and their self-confidence (Biotechnology concepts: 83%, M: 63%). This adheres to a previous study with clinical nutritionist students where

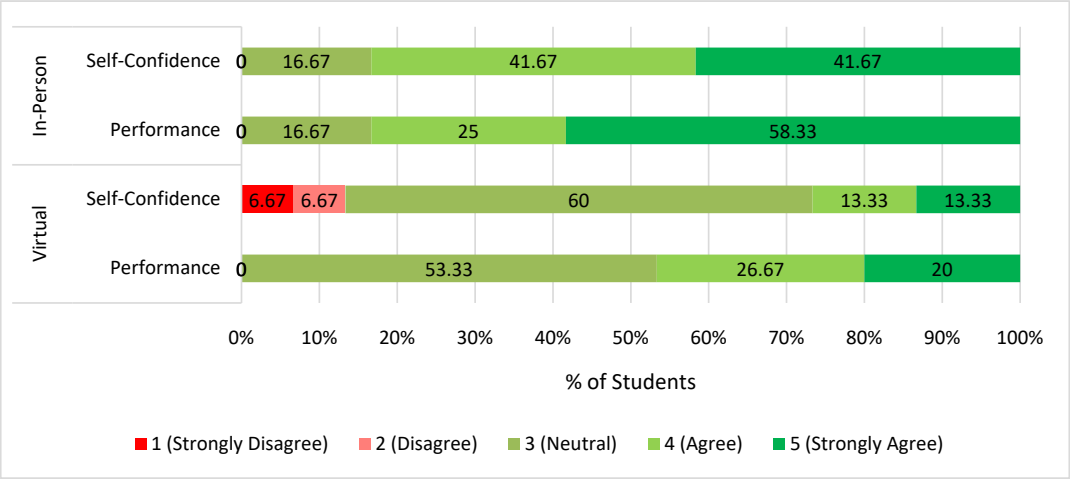

Figure 7. The effect of CBL on self-confidence and performance for students in the course Biotechnology Concepts.

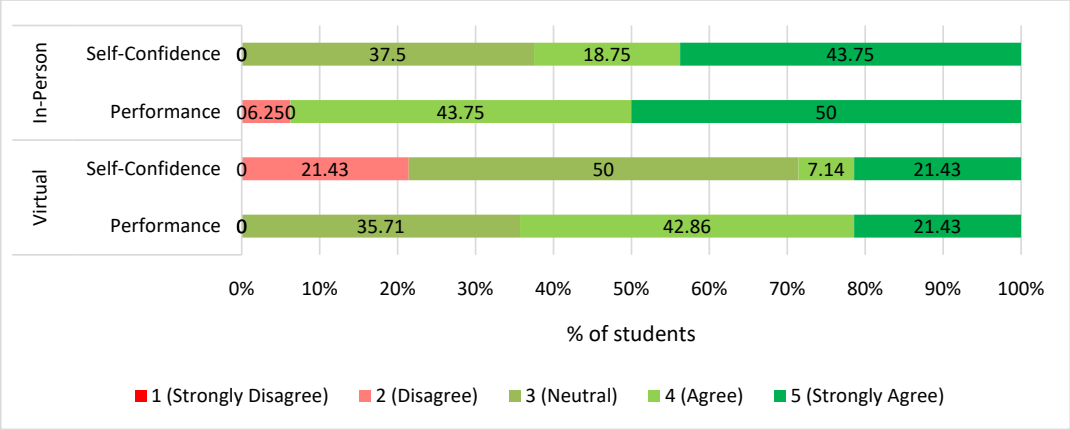

Figure 8. The effect of CBL on self-confidence and performance for students in the course Microbiology.

in-person CBL helped improve their self-confidence in addition to their performance (Farha et al., 2021). Another study conducted on undergraduate STEM students found that active learning helped enhance their performance (Freeman et al., 2014). Similarly, nursing students also showed that CBL not only helped with the students' critical thinking, but also helped with improving the students' self-confidence and academic performance (Ma & Zhou, 2022). On the other hand, for the virtual CBL, most of the students had a neutral viewpoint pertaining to the effects of CBL to their self-confidence (BC: 60%, M: 50%) and performance (BC: 53%) in both courses, except for in the course Microbiology where the majority agreed (64%). This indicates that the students perceive no effect of virtual CBL on their self-confidence and performance. As mentioned earlier, this might be due to the possible communication challenges in an online environment as these could affect the students' learning gains, thus affecting their performance in the course. Additionally, a previous study reported that the overall performance of students was higher when case studies were performed in groups as opposed to being done individually, resulting in boosting the confidence of

the student groups (Hautz et al., 2015). This entails that teamwork has a significant impact on the self-confidence and performance of students. Potential reasons as to why students perceived no effect of the virtual CBL on the mentioned attributes could be associated with communication challenges and the formation of randomized student groups.

3.5. Learning Experience

Learning experience is a very important aspect of CBL since it focuses on building an interactive and collaborative experiential student learning to meet the desired learning outcomes of the course. In the course Biotechnology Concepts (**Figure 9**), the students provided strong positive feedback for the in-person case studies compared to the virtual CBL. 92% of students agreed (50% agreed and 42% strongly agreed) to the statement that "case study improved my learning experience" for the in-person case studies while for the virtual case studies, only 40% agreed (27% agreed and 13% strongly agreed). More than half of the students, i.e., 53%, had a neutral perception about the effects of virtual CBL on their learning experience, while 8% were neutral for the in-person format. No students disagreed with this statement for the in-person cases, while only 7% disagreed for the virtual cases. On the other hand, in the Microbiology course (**Figure 10**), the majority agreed for both formats (virtual: 57%, in-person: 88%), some were neutral (virtual: 29%, in-person: 13%), while some disagreed (virtual: 14%, in-person: 0%). Thus, it could be inferred that the students had a more positive learning experience with in-person CBL compared to virtual CBL. In a previous study, it was found that students had a lower or worse learning experience in online environments compared to in-person (Nicklen et al., 2016; Dawson et al., 2021). However, another study stated the opposite where the students' learning experience were proved to have been better online (Chen et al., 2022). These mixed results could be due to many different factors which include different disciplines, different methods of CBL implementation, different methods of online learning, etc. In addition, other parameters including teamwork and communication could either influence the students' experience and satisfaction positively or negatively, which could result in creating a bias in the preference of students towards one mode of delivery. Essentially, these factors could eventually affect the overall learning gains and motivation for students as well.

3.6. Course Knowledge: Concept Understanding and Application, and Deeper Understanding

This study also examines the effect of CBL on course knowledge with a specific emphasis on concept understanding and application, and deeper understanding. **Figure 11** and **Figure 12** illustrate that most students for both courses agreed that in-person CBL improved their concept understanding (Biotechnology Concepts: 100%, Microbiology: 94%) and deeper understanding (BC: 83%, M: 81%). The students agreed that the in-person cases helped them both in understanding and applying their knowledge and providing a deeper understanding of the top-

ics. This is adherent with literature studies as CBL is an active learning method that has been used in different disciplines to connect the classroom to the industry through case studies (McLean, 2016). Furthermore, it also helped in deeper learning, which means, going beyond the answers and encouraging broader thinking via classroom discussions.

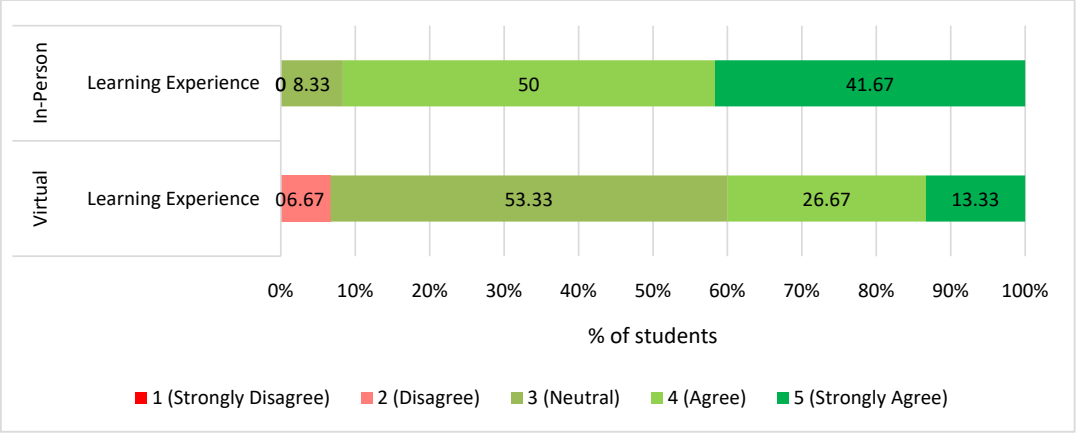

Figure 9. The effect of CBL on the learning experience of students in the course Biotechnology Concepts.

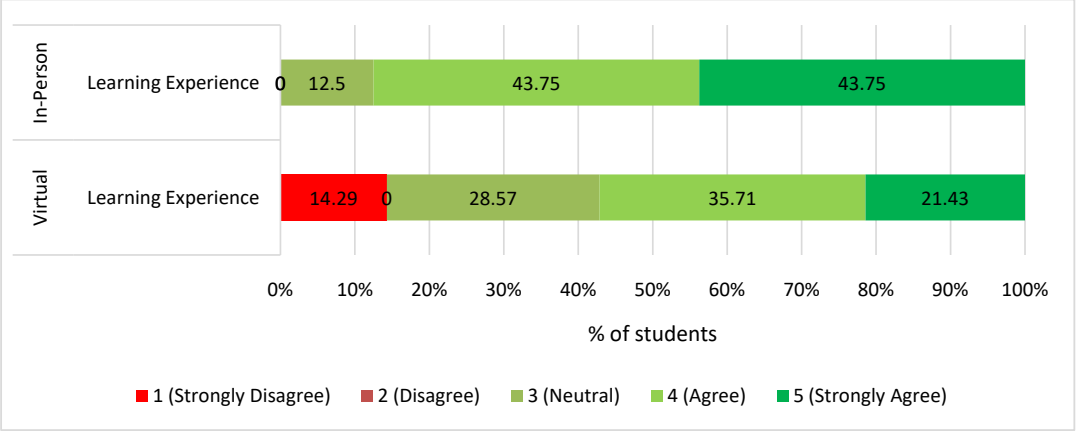

Figure 10. The effect of CBL on the learning experience of students in the course Microbiology.

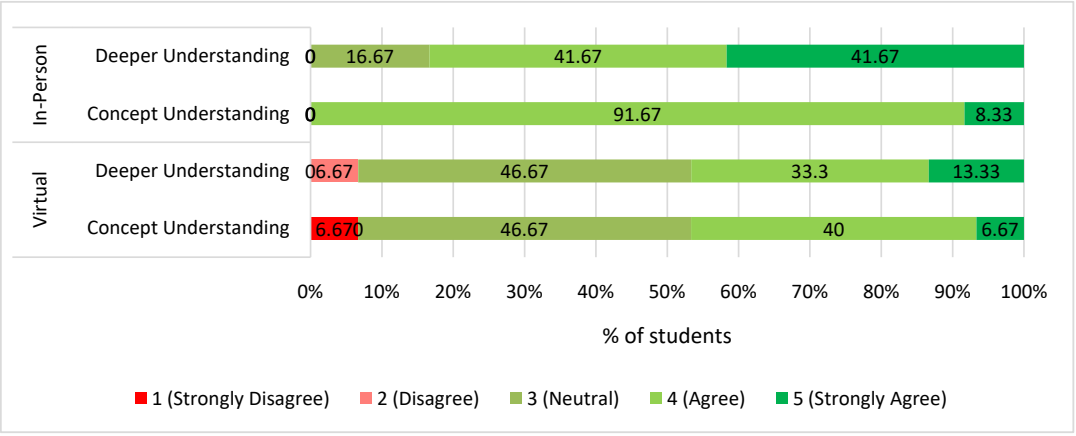

Figure 11. The effect of CBL on course knowledge for students in the course Biotechnology Concepts.

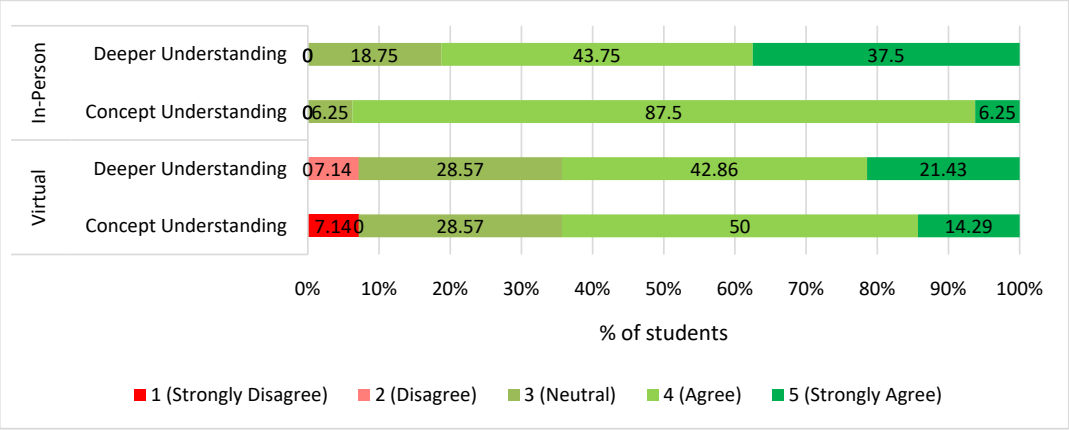

Figure 12. The effect of CBL on course knowledge for students in the course Microbiology.

For the virtual CBL, in the course Biotechnology Concepts, 47% of students agreed that CBL affected their course knowledge positively, 47% were neutral, and 7% disagreed; while in the Microbiology course, 64% agreed, 29% were neutral, and 7% disagreed. There were lower number of students that had a positive perception on the effects of CBL on course performance for the virtual CBL platform compared to the in-person CBL. Some factors that could have caused this difference are the topics of the course, and student experience during the active learning session. The course topics is one factor as the students had the virtual cases at the beginning of the term where the topics were mainly introductory and as discussed earlier, CBL is beneficial when students already know the topics. In addition, in a previous study, it was found that students had difficulties participating at the beginning, but improvements were done overtime, and the discussions and interactions eventually grew with time (Thibaut & Schroeder, 2022). Hence, having the virtual CBL at the beginning of the semester might have also affected the perceptions of students on its effects compared to the in-person cases. Another factor is student experience, which refers to how their team interacted during the session, if they conducted discussions during the session with each other rather than splitting the work and working by themselves, or if there were problems encountered during the session. This would have affected the quality of the students' interactions, while affecting their further understanding of the topic at the same time. Overall, the results demonstrate that while virtual CBL still had a positive effect on the students' understanding, it was not at the same extent as the in-person CBL, since some students even perceived that it had no effect.

3.7. Overall Evaluation

For the overall evaluation of students on the effects of the case studies, the results were analogous for both courses (**Figure 13** and **Figure 14**). In both courses the effects of in-person CBL was evaluated positively, with varying levels of agreement (Biotechnology Concepts: 42% agreed, 58% strongly agreed; Microbiology: 44% agreed, 56% strongly agreed), and zero disagreed or had a neu-

tral viewpoint. The virtual case studies, however, consisted of differing opinions. In Biotechnology Concepts, most students had a neutral perception (47%), followed by those who agreed (40%), then disagreed (13%) while in Microbiology, the percentage of students who agreed (43%) and were neutral (43%) were the same, and a portion who disagreed (14%). With that said, the values were around the same range, with no huge differences observed for both courses, signifying a similar overall evaluation of virtual and in-person CBL.

From this overall evaluation, it is evident that students were highly in favour of the in-person case studies which had a full positive evaluation compared to the virtual case studies, which had conflicting results between a neutral and positive perception. The results show that students did indeed perceive a difference between the two CBL formats. In the literature, some studies found that there was no significant difference between the in-person and virtual CBL and that both methods were comparable (Donkin et al., 2022, Anas et al., 2022). Some studies also found that online learning was preferred compared to the traditional face-to-face settings (Caroni & Nikoulina, 2021); while others found the opposite where in-person learning was preferred in other courses, disciplines and

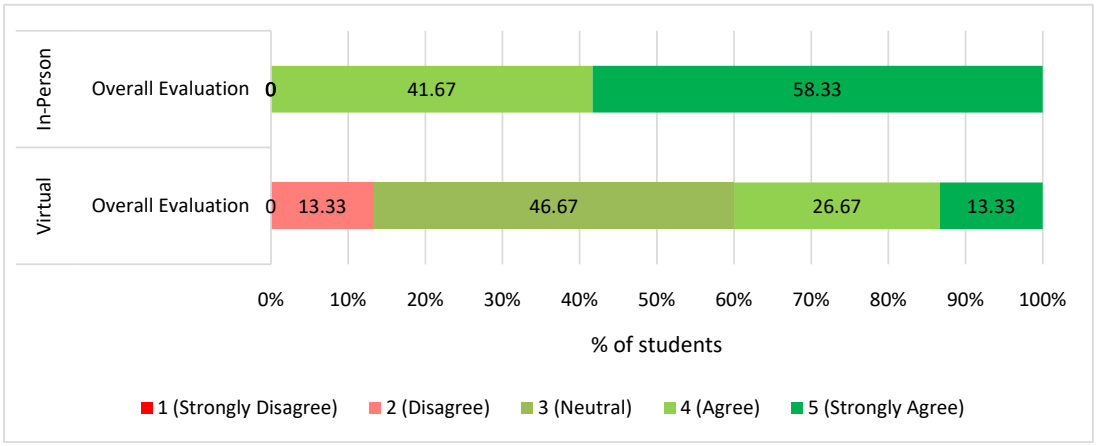

Figure 13. The overall evaluation on the effects of CBL for students in the course Biotechnology Concepts.

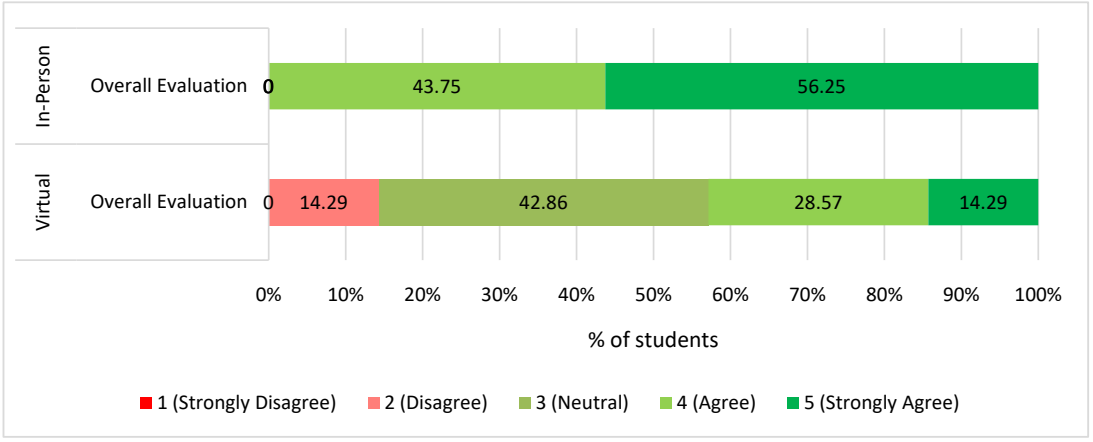

Figure 14. The overall evaluation on the effects of CBL for students in the course Microbiology.

universities (Alani & Grewal, 2024, Nicklen et al., 2016, Dalal et al., 2022). However, instructors found many challenges to the online case study such as difficulty to keep track of the learner and answers to many case studies questions are already available on the internet (Herreid et al., 2021). Many factors affect these results as mentioned previously. Further studies are needed to determine the effects of the format in which CBL should be delivered in the engineering technology discipline and effect on course outcomes. Nonetheless, whether the CBL format was in-person or virtual, it was quite well-received by the students during the semester and regardless of the format, case studies helped the students in their learning outcomes and experience in more ways than one.

4. Conclusion

In conclusion, the findings of this study reveal that students perceived the effects of CBL to be more positive for in-person CBL, compared to that of virtual CBL. The student experience with the virtual format and the circumstances during the study might have played a role in causing differences in how the students discerned between the two methods of delivery. Further studies are needed to verify and identify other limiting factors that could have caused the disparities between the two formats such as case material, the number of cases, the time of survey, control group, technical problem and potential frustration in virtual CBL. With that said, the results in this study were successful in indicating that for the in-person learning, the students were more astute on CBL having played an essential role in enhancing their personal skills (critical thinking, problem-solving, teamwork, communication, and real-life technical skills), performance and self-confidence, learning experience, and conceptual and deeper understanding of the course concepts. Moreover, these findings were alike for two different undergraduate engineering technology courses which reinforces the outcomes found in this study. This is important since CBL is used to connect the classroom to the industry, which is very much needed in the current workforce, especially in the engineering technology field. Furthermore, education is moving towards the online environment and determining the differences in the effects of virtual/online CBL compared to the in-person format would be beneficial in the development and implementation of CBL in other engineering technology courses.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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