Effect of Case-Based Learning (CBL) on Student Performance in Engineering Biotechnology Education*

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Case-based learning is a method that has been used increasingly in a variety of disciplines. However, in the engineering technology education, this method is still underutilized. The goal of this study was to evaluate the effect of case-based learning in the performance of engineering technology students. Students enrolled in an undergraduate biotechnology course answered an anonymous survey about the effects of CBL on different factors that are linked to improving their performance. The results demonstrate that CBL had a positive effect on the students' learning experience, concept understanding, and deep understanding for the course which contributed to the effectiveness of CBL in improving the students' performance. Furthermore, this study found that having more cases reviewed per term increased the student performance based on their final marks on the course, clearly indicating the positive impact of CBL on student performance.

Keywords: CBL; active learning; pedagogical research; student performance; engineering biotechnology

1. Introduction

Case-based learning (CBL) is a method that has been used in various disciplines where real-life scenarios from the industry are used for teaching. While it has been increasingly popular, especially in business, law, and medical education [1, 2], it is still an underutilized method in the engineering technology education. For this reason, there are limited studies existent which discuss case-based learning in engineering technology. One of the recent studies on CBL in engineering is a study conducted by Yadav et al. on mechanical engineering students which analyzed the students' perspectives of the effects of case studies [3]. Another study done by Garcia showcases the use of cases to increase learning and training to develop problem solving skills for civil engineering students [4]. A different study analyzed the students' perceptions of CBL and their learning outcomes [5]. Aside from essential skills, including problem solving, teamwork, and communication, which could be obtained from the application of CBL, some studies found CBL to be effective in achieving the learning outcomes and increasing the student performance as well [6–9].

CBL helped students to appreciate engineering and using their concepts in real-life industry [10], CBL also improved critical thinking, problem solving and communication skills, making learning more motivating and engaging [11].The effectiveness of case studies rated by engineering students and found CBL to be effective along all four dimensions of usefulness, challenging, attractiveness and clarity [12].The incorporation of CBL can help students in engineering and technology reflect critically by questioning their beliefs and practices and provide an array of choices to help evaluate situations with a more creative and pragmatic approach. Due to the active instructional approach of the CBL, it also provides a greater appeal among students who find it difficult to engage in a lecture-format based learning method which focuses merely on facts rather than the augmentation of critical and innovative thinking skills [13]. Vivas and Allada [14] reported that thematic case studies could bridge the gap between theoretical background and practice thematic. CBL combined with STEM education concept reported to improve the mean scores of nursing students associated with critical thinking, self-directed learning and self-efficacy as compared to those in a traditional teaching group [15].

The goal of this study is to assess the effectiveness of CBL on student performance. The students' perspectives on their learning experience, self-confidence, conceptual understanding, and deeper understanding are analyzed in this study in association with their performance. In previous studies, it was established that cases act as a link between theoretical concepts and practical applications [16].

Results from a study on biology students showed that combining case studies with a practical experiment on the same topic led to an increase in student learning and hence, resulted in increasing student performance [8]. Thus, case studies could essentially provide insights for the students and facilitate the understanding on how concepts learnt in lectures

and practiced in the laboratory are applied in the industry. In addition, learning experience could be enhanced by case studies due to the increased engagement and motivation of the students in class [5, 6]. Consequently, with the provided insight and the increased motivation of the students to learn, they would be able to gain a deeper understanding of the concepts, leading to an increase in the student performance in the course [5, 8]. In other words, CBL affects various interconnected factors that could potentially improve the students' performance in the course; of which are evaluated in this study.

2. Methodology

This study evaluates the effectiveness of CBL based on the students' performance in the undergraduate engineering technology education. Throughout this study, a blended teaching and learning method was used by alternating between traditional lectures and active learning technique, such as case studies as the only active learning technique. The study was conducted on two second year biotechnology courses namely Microbiology and Biotechnology concepts in winter 2019 with a total of 62 students, 31 for each course.

This study used an anonymous survey questionnaire evaluating the effect of CBL on the course performance, self-confidence, learning experience, concept understanding, and deep understanding of the students. The participants responded to the questions based on a five-point scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, to 5 = strongly agree). The case studies were solved in class by student teams, each team consists of three students with the instructor as facilitator. There were ten case studies over the term for Biotechnology concepts course, one case study every week except first and last weeks of the term. While, there were five case studies over the term for Microbiology course one case study every other week except first and last week of the term. The topic of the weekly or biweekly case studies were related to the lecture topic of that week for example the case study "Sustainable nitrogen-producing microbe for corn reduces need for chemical fertilizer" was used as application for the chapter Microbial biotechnology in the biotechnology course concepts. The case study "The Path of a Pathogen" was used as application of chapter on the microorganisms and diseases in the microbiology course.

3. Results and Discussion

The results shown are based of the combined results from the two courses

3.1 Effect of CBL on Course Performance

The result of the combined courses is depicted in Fig. 1, 47% of the students agreed that CBL improved their course performance (17% strongly agreed and 30% agreed); 20% of the students disagreed (3% strongly disagreed and 17% disagreed); and 33% were neutral. The students had varying opinions about the effect of CBL on their performance, which could be due to the differences on how each individual student perceives they are learning in class. In previous studies, it was found that students know less than what they think they learnt from lectures and hence, might not notice the knowledge they gain from studying cases [5]. This implies that some students might believe they are learning lesser from case studies than actual lectures and thus, have the perception of performing less in the course. Oppositely, some students might regard cases to have helped them in increasing their learning for the course [3]. The differences in student
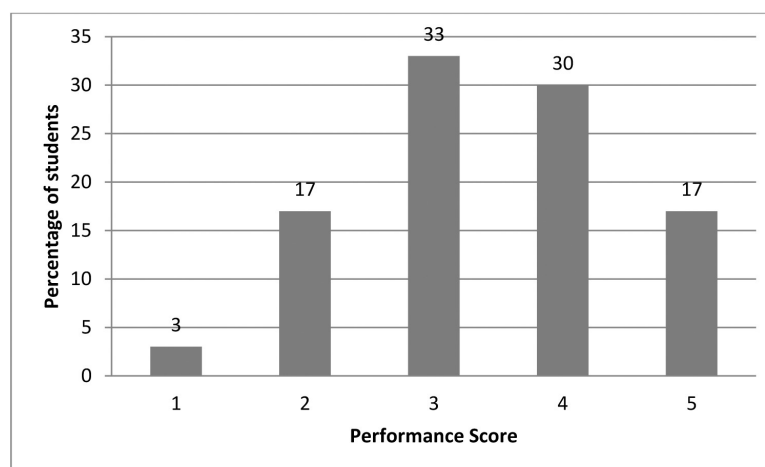

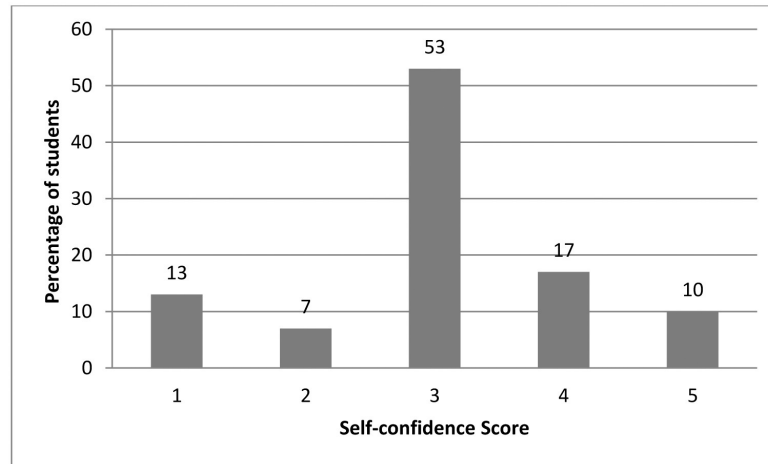**Fig. 1.** Effect of CBL on student performance in the course.

Fig. 2. Effect of CBL on the student self-confidence.

perceptions of their learning and resultant perfor-mance is responsible for the different results obtained from the survey.

3.2 Effect of CBL on Self- Confidence

The effect of CBL on enhancing the students' self-confidence to create plausible application ideas of the concepts is shown in Fig. 2. In this parameter, over half (53%) of the students responded neutral as to whether CBL enhanced their self-confidence, while 27% of the students agreed that CBL enhanced their self-confidence (10% strongly agreed and 17% agreed), and 20% of the students disagreed (13% strongly disagreed and 7% dis-agreed). From these results, most responses were neutral which signifies that the students believed that CBL did not change their self-confidence in their knowledge application. This may need further investigation of the effect of CBL on the different components of self confidence.

3.3 Effect of CBL on Learning Experience

As Fig. 3 illustrates, most of the students (73%) agreed that CBL improved their learning experience (35% strongly agreed and 38% agreed), while 21% were neutral and 6% disagreed. In this parameter, the majority of the students' responses were mostly in agreement which shows a positive assimilation for CBL. This is in line with the results of other researchers where it was found that CBL makes students more engaged during class thus, changing their learning experience compared to traditional lecture-based teaching [4, 5]. The use of CBL, by its nature, causes change in the students' learning experience compared to the conventional lecture-based experience of students in the class. This helps in proving that CBL is positively correlated in improving the learning experience for students.

3.4 Effect of CBL on Concept Understanding
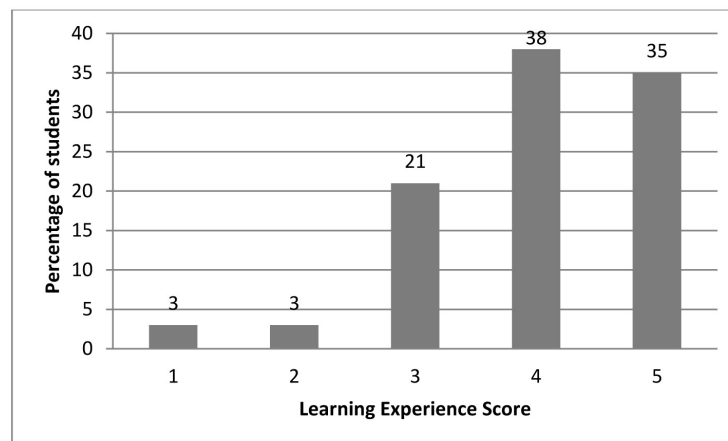
In Fig. 4, 68% of the students agreed that CBL

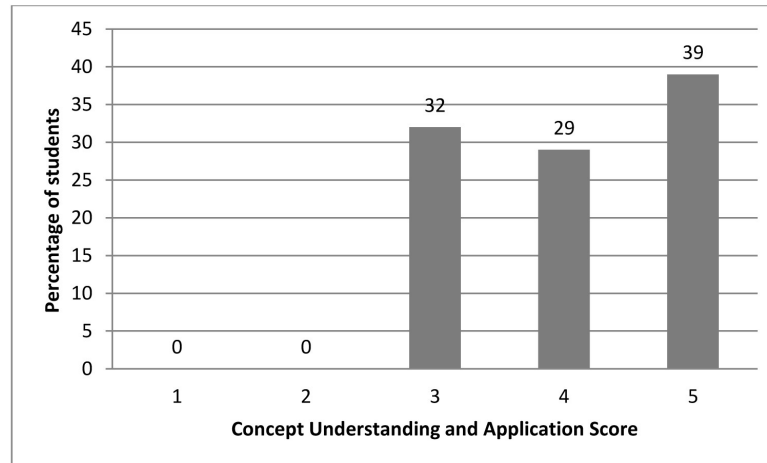**Fig. 3.** Effect of CBL on the student learning experience.

Fig. 4. Effect of CBL on the students understanding of concepts and their applications.

enhanced their understanding of concepts and their respective applications (39% strongly disagreed and 29% agreed), while 32% were neutral. This is the only parameter in which no students disagreed (0% disagreed). These results correlate with previous studies where it was found that students find that case studies help in linking the curriculums' concepts to real-life scenarios and applications better compared to traditional lecture-based learning [3, 5]. Since CBL uses actual scenarios from the industry, it certainly allows for better visualization of the possible applications of the concepts in the industry. Furthermore, by having a glimpse of the applications, it allows for a better understanding of the concept's functionality, leading to an increase in the student performance.

3.5 Effect of CBL on Deep Understanding

The effect of CBL on the deep understanding of the students is shown in Fig. 5. Most of the students (60%) agreed that CBL helped them in developing a deeper understanding (27% strongly agreed and 33% agreed), while 34% were neutral and 6% disagreed. These results can help conclude that from the students' perspective, CBL helped them in achieving a deeper understanding of the course concepts. This is similar to the results from other studies where it was found that cases helped students look at the concepts from different perspectives in addition to the usual academic memorization of the topic [3, 4]. CBL helps in the deep understanding of the students since it lets them be more aware of the environment surrounding the topic, providing them with a better understanding of the subject itself including the factors that could potentially be affected around it.

3.6 Number of Preferred Case Studies per Term

Fig. 6 displays the results of the students' preferred number of case studies per term. Ninety percent of the students preferred the use of case studies, 48% chose 5 case studies while 42% preferred to have 10
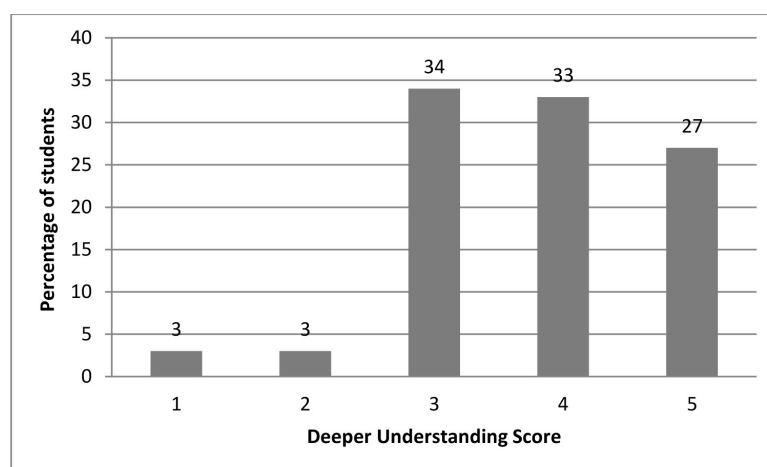

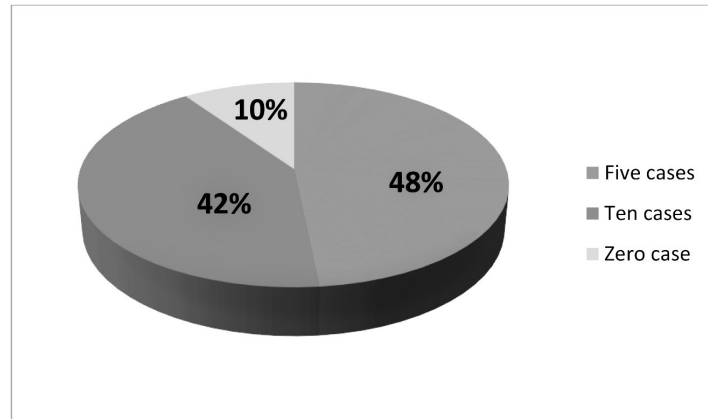**Fig. 5.** Effect of CBL on the students deeper understanding.

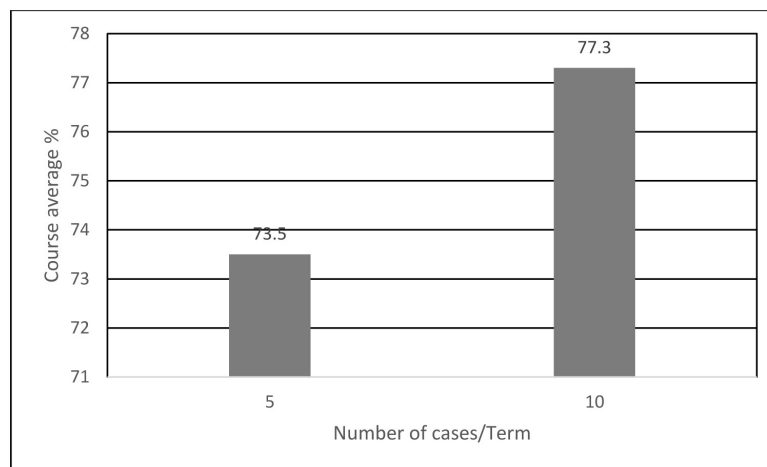**Fig. 6.** Number of preferred case studies per term.

Fig. 7. Effect of case study number on student course average.

cases per term, while the remaining 10% stated that they would like to have no case studies at all. These results imply that although there are some students that preferred to not have any case studies during the term, the majority of the participants have a positive feedback in solving case studies in class. This supports the study conducted by Yadav et al. [3] where despite the benefits of CBL, there would be some resistance against it and precautions must be taken when implementing CBL.

3.7 Effect of CBL on Student Course Average

Fig 7. shows the average of the students' final grades for the course in the two different classes: the first with 5 case studies and the second with 10. Comparing the results, it is evident that the class with 10 case studies had a slightly higher average of 77.3% compared to the 73.5% of the class which implemented 5 case studies during the term. These results help insinuate that studying more cases resulted in the students performing better, which directly correlates with the effectiveness of CBL in

enhancing the students' performance. In addition, this reinforces the results obtained from other studies where the students' judgement of their learning and performance did not match what they actually learnt [5]. That is to say, in contrast to students' perceptions of their performance, their actual final marks show that CBL helped in increasing the students' performance in the course.

4. Conclusions

In conclusion, the results of this study found that students feel that CBL did have an effect on improving the performance in undergraduate biotechnology courses. While some students had varying opinions, most of them found that in addition to improving their learning experience, CBL also enhanced their conceptual understanding and induced a deeper understanding of the course concepts. Conversely, the majority of the students preferred to have case studies, with more than half of them choosing less cases to be solved per term

and had differing thoughts on whether CBL improved their course performance. However, the final student course average suggests otherwise. This is because the class which implemented more case studies resulted in a higher final average compared to the class with lesser cases. This sup- ports the fact that CBL does improve student performance and is directly affected by the quantity of cases. Nonetheless, further studies on the appli- cation of CBL on other engineering courses are required in order to gain more understanding of the effects of CBL on students' performance.

References

1. J. Henderson, *Reflective teaching: Professional artistry through inquiry* (3rd ed.), Upper Saddle River, NJ: Merrill/PrenticeHall, 2001.
2. S. Klein (ed.), *Teaching art in context: Case studies for art education*, Reston, VA: National Art Education Association, 2003.
3. A. Yadav, C. Bozic, S. Gretter and E. Nauman, Benefits and Challenges of Implementing Case-based Instruction: A Student Perspective, *Int. J. Eng. Educ.*, **31**(6(A)), pp. 1554–1563, 2015.
4. J. Garcia, J. Sinfield, A. Yadav and R. Adams, Learning Through Entrepreneurially Oriented Case-Based Instruction, *Int. J. Eng. Educ.*, **28**(2), pp. 448–457, 2012.
5. A. Yadav, V. Alexander and S. Mehta, Case-based Instruction in Undergraduate Engineering: Does Student Confidence Predict Learning?, *Int. J. Eng. Educ.*, **35**(1(A)), pp. 25–34, 2019.
6. J. Zarrajeria and B. G. Zapirain, Using Actual Cases of Pathological Speech Improvement to Teach Digital Signal Processing, *Int. J. Eng. Educ.*, **32**(2(A)), pp. 830–840, 2016.
7. F. Alani, Development of Case-Based Learning (CBL) in Engineering Technology Education, *Int. J. Eng. Educ.*, **36**(3), pp. 896–900, 2020.
8. K. M. Bonney, Case Study Teaching Method Improves Student Performance and Perceptions of Learning Gains, *Journal of Microbiology & Biology Education*, **16**(1), pp. 21–28, 2015.
9. M. Krain, Putting the Learning in Case Learning? The Effects of Case-Based Approaches on Student Knowledge, Attitudes, and Engagement, *Journal on Excellence in College Teaching*, **27**(2), pp. 131–153, 2016.
10. A. Yadav, M. Vinh, G. Shaver, P. Meckl and S. Firebaugh. Case-based instruction: Improving students' conceptual understanding through cases in a mechanical engineering course, *Journal of Research in Science Teaching*, **51**(5), pp. 659–677, 2014.
11. A. Yadav, V. Alexander and S. Mehta. Case-based Instruction in Undergraduate Engineering: Does Student Confidence Predict Learning? *Int. J. Eng. Educ.*, **35**(1(A)), pp. 25–34, 2019.
12. P. K. Raju and C. S. Sankar, (1999). Teaching real-world issues through case studies. *Journal of Engineering Education*, **88**(4), 501–508.
13. C. L. Bozic and N. W. Hartman, (2014). Case-Based Instruction for Innovation Education in Engineering and Technology. *121st ASEE Annual Conference and Exposition*, Indianapolis, IN.
14. J. Vivas and V. Allada, Enhancing Engineering Education Using Thematic Case-Based Learning, *Int. J. Eng. Educ.*, **22**(2), pp. 236–246, 2006.
15. X. Zhu, Z. Xiong, T. Zheng, L. Li, L. Zhang and F. Yang. Case-based learning combined with science, technology, engineering and math(STEM) education concept to improve clinical thinking of undergraduate nursing students: A randomized experiment, *Nursing open*, **8**(1), pp. 415–422, 2020.
16. J. E. Thistlethwaite, D. Daives, S. Ekeocha, J. M. Kidd, C. MacDougall, P. Matthews, J. Purkis and D. Clay, The effectiveness of case-based learning in health professional education. A BEME systematic review: BEME Guide No. 23, *Medical Teacher*, **34**(6), pp. e421–e444, 2012.

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