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Perspectives of Advanced Biotechnology Undergraduates on the Effect of Case-Based Learning on their Individual Academic Achievements*

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Case-based learning (CBL) is an active learning modality customarily underutilized in the undergraduate engineering technology education. The prime purpose of this pedagogical study was to analyze student perspectives on the effect of CBL on their individual learning in the undergraduate advanced biotechnology course completed in fall 2019. The resultant findings from the survey showcased CBL having improved critical thinking, problem solving, teamwork, communication, real-life technical skills, course performance, self-confidence, and the overall learning experience for the students. Additionally, it was found that CBL enhanced concept understanding, application, and induced a deeper conceptual understanding amongst the upper year students much more significantly as opposed to the lower year students.

Keywords: CBL; active learning; biotechnology; engineering technology; education

1. Introduction

Biotechnology is a surging field in engineering technology education comprised of chemical, biochemical and biomedical sciences integrated with business management. With the field's strong emphasis on developing practical skills and providing students with a hands-on experience, case-based learning (CBL) is an active learning pedagogical approach used in biotechnology to help students bridge the gap between their established skills and industry practices prior to setting foot out into the professional world.

The complex stature of the current biotech industry with increasing challenges associated with R&D, drug development and pharmacogenomics has been evident during the ongoing Covid-19 pandemic. This requires the need to reform and reshape the present academic curriculum to create future leaders capable of facing tomorrow's uncertainties. Being successful in the biotech industry is only partially dependent on scientific and technical skills, with the knowledge of business, resource management and teamwork skills equally significant [1].

CBL is an inquiry-based active learning technique commonly used in various undergraduate fields including clinical, medical, law and business management education. This method aims to replace traditional teaching methods with a more active instructional based approach. Although the outcomes of case studies are already known, they can help students prepare, identify, and govern problems that global industries face with a "fresh perspective" [1] and hence, develop skills extremely essential for future career opportunities.

The incorporation of CBL in undergraduate engineering technology education has known to devise a sense of realism to the academic content [2]. Bozic and Hartman's [3] findings concluded that students found cases studies to be an effective learning tool with an interactive learning environment to solve real-life tangible problems focused on innovation education. CBL combined with STEM education concept [4] was also 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. Additionally, the incorporation of CBL has proven to augment the grades of students with a lower academic performance, with their overall learning experience defined as "engaging", "fun", and "thought-provoking" [5].

With students not being able to envision the real-world applications of their learning due to the underutilization of active learning methods in the engineering curriculum has resulted in numerous students to withdraw from engineering [6]. A survey conducted by Yadav et al. [7] proclaimed that students associated CBL in helping them appreciate engineering and applying their concepts effectively to real-life industry problems. CBL has been positively correlated in improving critical thinking, problem solving and communication skills, making learning more motivating and engaging, and improving the overall learning experience for engineering students [8].

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2. Methodology

This research is based on a pedagogical study conducted to analyze students' perspectives on the incorporation of CBL into the undergraduate biotechnology education curriculum. The study focuses on the applications of CBL in the fourth-year undergraduate advanced biotechnology course completed in fall 2019. The course consisted of a blended teaching approach harmonized with lectures, project-based learning, and active learning methods such as the CBL. The total number of students/respondents (n) who participated in this study were 13 and the survey was performed at the end of the term.

The impact of CBL on student performance was analyzed by conducting an anonymous survey questionnaire comprised of 12 questions. The survey evaluated the effect of CBL on critical thinking, problem solving, teamwork, communication skills, real-life technical skills, course performance, self-confidence, learning experience, concept understanding and application, and deeper understanding. The student responses were documented based on a five-point ranking 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, one case study every week except first and last weeks of the term. The topic of the weekly case studies was related to the lecture topic of that week for example the case study "Bioengineering the Pancreas/ Developing novel regenerative therapies to address Type 1 diabetes" was used as application for the chapter of tissue engineering in the course [9].

3. Results and Discussion

3.1 Effect of CBL on Critical Thinking

Fig. 1 showcases the student responses associated with CBL having improved their critical thinking with 54% students having agreed with this statement (38% agreed and 16% having strongly agreed). On the other hand, 38% of students were neutral towards this statement whereas, 8% disagreed. The result complies with the conclusions from studies [4, 8] discussed and indicates that CBL is indeed responsible for insinuating a more critical and pragmatic thinking approach for the purposes of decision making.

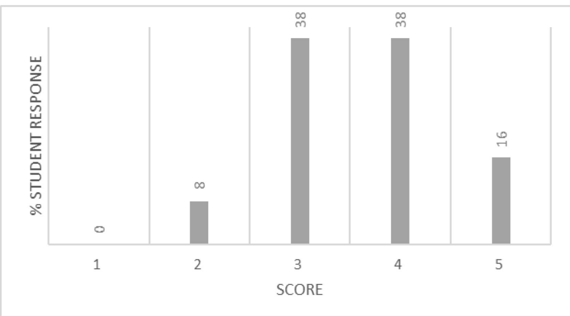

Fig. 1. CBL improved my critical thinking.

3.2 Effect of CBL on Problem Solving

The effect of CBL in helping students problem solve is depicted in Fig. 2. Sixty-one percent students agreed with this statement, with 31% having a neutral viewpoint and the remaining 8% having disagreed with this statement. The majority having complied with this statement suggests that case studies are an essential tool in helping students solve real-life industry problems and in preparing them to work in complex environments in the future.

3.3 Effect of CBL on Teamwork

Fig. 3 displays the effect of CBL on teamwork with 69% students having agreed with this statement (54% agreed and 15% strongly agreed), 23% students having abstained and 8% having disagreed. With the requirement for case-studies to be solved collaboratively in groups of three and then to be openly discussed with the instructor, students can

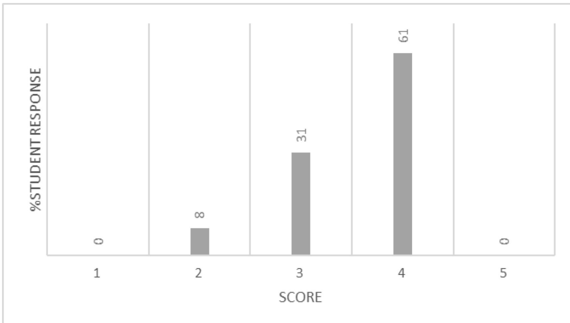

Fig. 2. CBL helped me in problem solving.

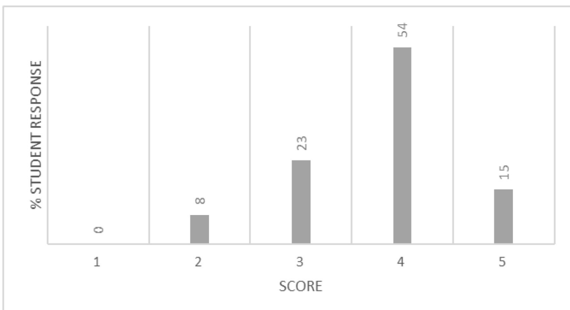

Fig. 3. CBL helped in teamwork.

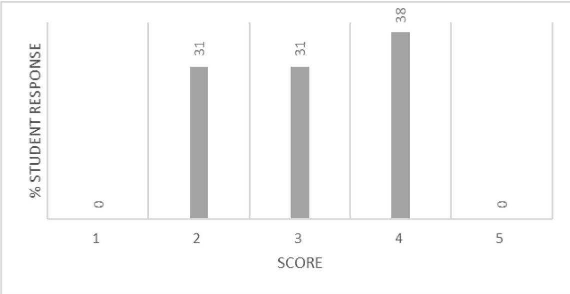

Fig. 4. CBL improved my communication skills.

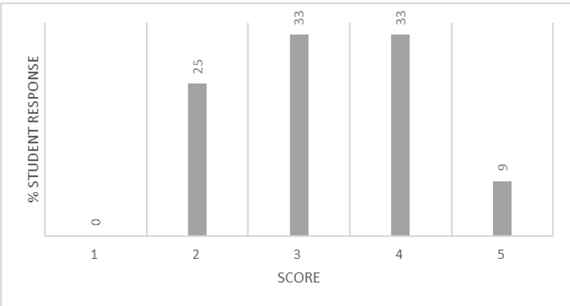

Fig. 5. CBL improved my real-life technical skills.

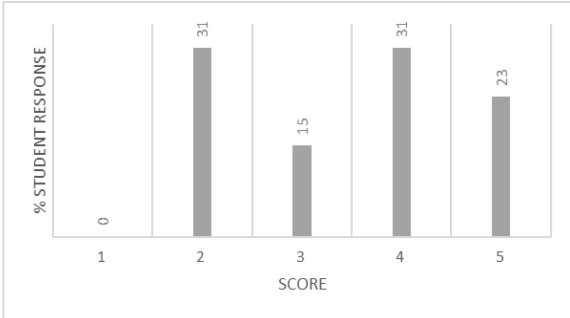

Fig. 6. CBL improved my performance in the course.

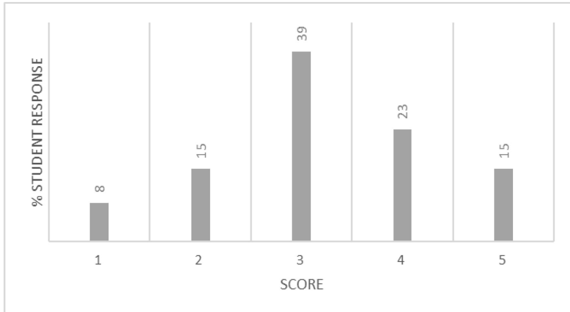

Fig. 7. CBL enhanced my self-confidence.

apply the best viable option to resolve the case study via practicing teamwork.

3.4 Effect of CBL on Communication Skills

The effect of CBL on communication skills is illustrated in Fig. 4. Thirty-eight percent of the participants agreed with CBL having improved their communication skills while contrastingly, 31% perceived neutrality towards this statement and the remaining 31% disagreed. Although CBL encourages both oral and written communication, the active classroom discussions tend to emphasize oral communication more. This helps explain the contrasting opinions of the students, for some might be more comfortable in expressing their opinions through written communication as opposed to oral.

3.5 Effect of CBL on Real-Life Technical Skills

Fig. 5 exhibits the effect of CBL on improving real-life technical skills for the students. Forty-two percent students complied with this statement (33% agreed and 9% strongly agreed), 33% were neutral, whereas 25% disagreed. CBL has been directly associated with the development and enhancement of technical skills necessary to confront real-life industry affairs [10].

3.6 Effect of CBL on Course Performance

The effect of CBL in improving course performance is presented in Fig. 6 with 54% students affirming with this statement (31% agreed and 23% strongly agreed). On the other hand, 15% voiced that CBL neither improved nor demoted their course performance and the remaining 31% felt that CBL did not improve their course performance. The graph entails that CBL played a major role in improving the course performance for majority of the students, parallel with Zhao and his colleague's findings [11].

3.7 Effect of CBL on Self-confidence

Fig. 7 presents the effect of CBL in enhancing self-confidence for the students. Thirty-eight percent of the participants agreed with this statement (23% agreed and 15% strongly agreed), 39% were neutral and 23% disagreed (15% disagreed and 8% strongly disagreed). The result connotes that nearly 39% of the participants responded with CBL neither having enhanced nor lowered their self-confidence. This suggests that although CBL is directly linked in enhancing "learning confidence" [8] among students in their ability to problem solve, it may not necessarily enhance self-confidence to be applied in other categories.

3.8 Effect of CBL on Learning Experience

The effect of CBL in improving the learning experience in the course for students is depicted in Fig. 8. Sixty-one percent of students agreed with CBL having improved their learning experience (46% agreed and 15% strongly agreed), 31% perceived neutrality and 8% disagreed with the statement.

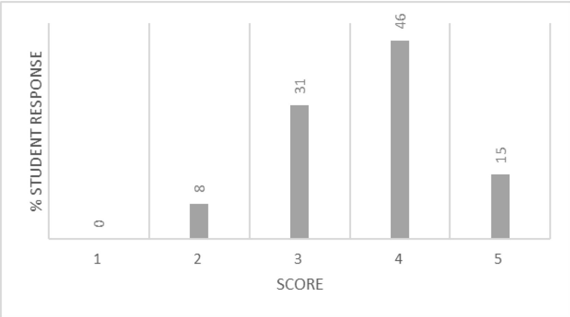

Fig. 8. CBL improved my learning experience.

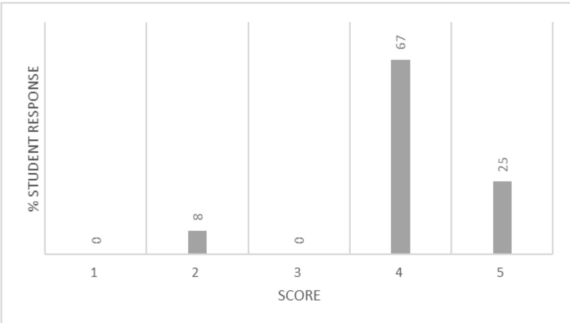

Fig. 9. CBL enhanced my concept understanding and application.

Majority participants having complied with the statement suggests that the incorporation of the active learning technique into the undergraduate biotechnology curriculum has contributed to improving and promoting learning, abiding with Bonney's [10] findings.

3.9 Effect of CBL on Concept Understanding and Application

Fig. 9 illustrates the effect of CBL in enhancing concept understanding and application for students. Ninety-two percent of the participants complied with this statement (67% agreed and 25% strongly agreed), whereas the remaining 8% disagreed. Since CBL engages students via the use of real-life cases, this results in enhancing conceptual understanding of course ideas. The students can associate course concepts with the real-life cases and hence, envision the palpable applications linked with the course concepts.

3.10 Effect of CBL in Deeper Understanding

The effect of CBL in helping induce a deeper academic and conceptual understanding among students is depicted in Fig. 10. Ninety-two percent of the students agreed with this statement (75% agreed and 17% strongly agreed), while 8% disagreed. CBL has known to help students establish an improved and deeper understanding of concepts in undergraduate engineering courses as opposed to

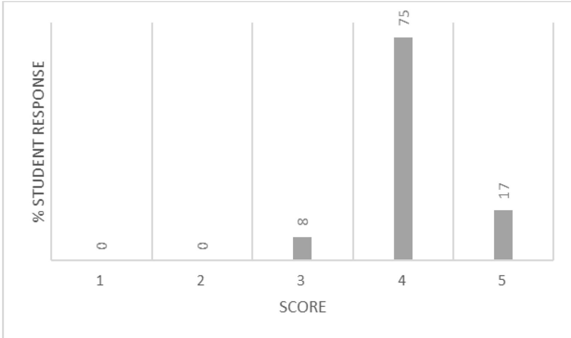

Fig. 10. CBL helped in deeper understanding.

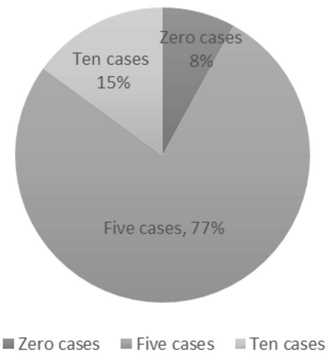

Fig. 11. Number of cases studies students prefer to solve per term.

traditional style lectures [10]. Additionally, case studies extend beyond factual learning and provide a deeper insight of real-life industry scenarios.

3.11 Number of Case Studies per term

Fig. 11 represents the number of case studies students suggested to be solved per one academic term. Fifteen percent students recommended solving 10 cases, 77% preferred 5 cases whereas, 8% suggested no case studies be solved. While the majority suggested 5 case studies to be solved per term, the 8% who wished for no case studies at all could be due to the varying differences in learning styles among each individual student. Conjointly, hindrances in the implementation process of CBL can give rise to varying opinions.

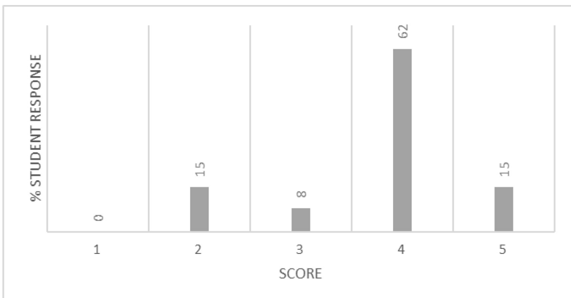

Fig. 12. Overall student evaluation of CBL.

3.12 Overall CBL Evaluation

The overall student evaluation regarding the implementation of CBL into the undergraduate biotechnology curriculum and its respective outcomes versus traditional lectures only was primarily positive. Seventy-seven percent of participants agreed that CBL proved to be an effective learning tool (62% agreed and 15% strongly agreed), 8% perceived neutrality towards this statement whereas, 15% disagreed (Fig. 12). The results imply that CBL deemed an effective tool in bringing real cases and scenarios from industries to life. CBL allowed the students to step into the shoes of the authority and take the cases upon their shoulders to best analyze and resolve them collaboratively.

3.13 Comparisonal Studies

Previous studies associated with the effect of CBL on student learning in the second [9, 12] and third years [13] of the undergraduate biotechnology program can be compared with this study to best see the effect of CBL at the various undergraduate years of study. Survey results based on the development of CBL in engineering technology education for second year and third year biotechnology students has been combined with the findings from this study in Table 1.

The resultant data from combining the effect of CBL on students in all three undergraduate years of study in Table 1 suggests that CBL helped improve the critical thinking, problem solving, teamwork and communication skills for third year students more as opposed to second year students. Another interesting finding was that 100% of the third-year students voiced that CBL helped them build teamwork and allowed them to collaboratively solve cases.

Contrarily, it was found that the percentage of second-year students who found CBL to have impacted their course performance, self-confidence, learning experience, concept understanding and application, and induce a deeper understanding was much lower as opposed to third year students. With third year students already having experienced a mandatory four-month term co-op placement and completed a greater number of case studies than second-year students, it is expected of them to agree more strongly with the effects of CBL on their individual learning.

Comparing the data from the second- and third-year students with fourth year students, it was found that the effect of CBL in enhancing critical thinking, teamwork, communication skills, real-life technical skills, course performance, self-confidence and learning experience was significantly lower for the fourth-year students. With fourth year students already having had the opportunity to have completed their 12-month mandatory co-op experience, it is expected of them to regard and give credit for the development of their essential skills to their careers and not active learning educational techniques.

Contrastingly, the effect of CBL in enhancing concept understanding and application and inducing a deeper understanding was undeniably higher for fourth year students as opposed to third year students. This implies that the fourth-year students were able to apply the concepts learnt from the real-life case studies completed in the classroom and apply their conceptual knowledge effectively at their co-op placements.

Education in the lower years of an undergraduate program is generally associated with teaching the fundamentals necessary to learn, while the upper years are educated on the ability to understand and apply the concepts learnt to their respective field of study. This abides with the principles behind the

Table. 1. Combined survey results from all three years of the undergraduate biotechnology program

	2nd year students			3rd year students			4th years students		
	Agreed	**Neutral**	**Disagreed**	**Agreed**	**Neutral**	**Disagreed**	**Agreed**	**Neutral**	**Disagreed**
Critical thinking	64%	23%	13%	77%	15%	8%	54%	38%	8%
Problem solving	54%	29%	17%	62%	38%	0%	61%	31%	8%
Teamwork	74%	26%	0%	100%	0%	0%	69%	23%	8%
Communication skills	55%	39%	6%	77%	23%	0%	38%	31%	31%
Real-life technical skills	50%	33%	17%	46%	42%	12%	42%	33%	25%
Course performance	47%	33%	20%	59%	37%	4%	54%	15%	31%
Self-confidence	27%	53%	20%	42%	46%	12%	38%	39%	23%
Learning experience	73%	21%	6%	85%	15%	0%	61%	31%	8%
Concept understanding & application	68%	32%	0%	82%	18%	0%	92%	0%	8%
Deeper understanding	60%	34%	6%	78%	22%	0%	92%	0%	8%
Overall CBL evaluation	71%	16%	13%	82%	18%	0%	77%	8%	15%

formation of Bloom's taxonomy, which focuses on providing students with a pertinent depth of learning via the three learning domains: cognitive, affective and the psychomotor domain.

The first domain in the hierarchy i.e., the cognitive domain is focused on building a knowledge base for students by helping them establish intellectual skills such as critical thinking. This is complementary to the findings of Alani's study [12] with CBL enhancing the critical thinking skills for second year students more than that for fourth year students.

The affective domain extends to receiving, listening, characterizing, and analyzing information to help students understand how their skills were developed. This domain can be directly associated with more third year students having agreed with CBL enhancing their teamwork, communication, real-life technical skills, course performance, self-confidence and learning experience as opposed to second and fourth year students.

The psychomotor domain is the last realm in Bloom's hierarchy of learning and constitutes the ability of students to physically execute and accomplish tasks. The findings from this study can be explicitly linked with this domain with CBL's role in enhancing concept understanding, application, and inducing a deeper understanding greater amongst fourth year students compared with students in lower academic years. Being in the last semester before graduation and already having completed numerous case studies throughout each academic year conjectures fourth year students already having developed integral technical skills. This necessitates the need for them to move beyond learning technical skills and focus on the synthesis, implementation, and application of their established skills in the industry.

It is imperative to recognize and acknowledge that the survey results are based on student perceptions on the effect of CBL on their individual learning outcomes and hence, not a true representation of their actual learning outcomes [8]. Conjointly, extensive variability exists in the data due to the number of participants being different for each study and each individual student having or have not had an exposure to a co-op opportunity. The variability present amongst each individual student's unique learning style was also not taken into consideration while implementing the active learning technique.

4. Conclusions

The complex and challenging environment of the current biotechnology industry requires the implementation of active learning techniques such as the CBL for students to effectively apply their knowledge to best analyze real-life industry problems. Programs must be designed to prepare students to face potential challenges than merely making them memorize concepts to be tested on, for the real test begins when they step out into the professional industry.

This study highlights the importance and relevance of incorporating CBL into the lower and upper years of the undergraduate engineering technology curriculum due to the numerous positive outcomes discussed. The findings help conclude that CBL deemed an effective learning tool for fourth year undergraduate biotechnology students in enhancing their concept understanding and application, and in inducing a deeper conceptual understanding as opposed to second- and third-year students. Additionally, CBL was found to have improved critical thinking, problem solving, teamwork, communication, real-life technical skills, course performance, self-confidence, and the overall learning experience for the students.

The findings of this study and previous studies also suggest that each learning domain in Bloom's taxonomy directly corresponds to the effect of CBL on student learning in each undergraduate academic year. Therefore, each academic year is directly representative of each learning domain in the hierarchy. We may need in the future to repeat this study for several years and cohort and have statistical analysis about the different cohorts.

The resultant findings insinuate that the implementation of CBL allowed the students to undergo a full range of engineering experience and helped in establishing essential skills necessary for their future careers. Further studies can be conducted with graduate students from engineering technology to best examine how they are applying concepts learnt via CBL during their undergraduate studies into their respective industries today.

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