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Navigating the Terrain:

Emerging Frontiers in Learning Spaces, Pedagogies, and Technologies

Future Direction of Biomedical Engineering Education in the Post-COVID-19 Pandemic Era: A Constructivist Perspective

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This study investigates the future direction of biomedical engineering education in higher education. It examines the perceptions of learning activities, modes, and styles among a group of biomedical engineering students at an Australian university. The survey findings reveal that both traditional and progressive pedagogies are preferred by the respondents. This paper concludes that traditional face-to-face lecturing maintains its value in biomedical engineering education.

Keywords: Active learning; biomedical engineering education; constructivist; post-COVID19; quantitative; survey

Introduction

The COVID-19 pandemic necessitated a shift to Emergency Remote Teaching (ERT), prompting a reassessment of traditional versus progressive pedagogies in biomedical engineering education. This study examines this dichotomy through the constructivist lens, based on survey findings on the participation, effectiveness and preference levels in various learning activities and styles perceived by a group of biomedical engineering students. Christie and de Graaff (2017) discussed the philosophical and pedagogical foundations of active learning in engineering education, highlighting the dichotomy between traditional and progressive approaches. Traditional education is structured and didactic, typically delivered through lectures, tutorials, and lab work. In contrast, progressive education is student-centred, flexible, and often involves problem-based, project-based, or group-based work.

The Constructivist Theory of Learning posits that student active agency underpins learning whereby students assume an active rather than passive role in learning and constructing knowledge aided by internal and/or external resources such as schema, socio-cultural environment, mentorship, and cultural tools. It is derived from Constructivism and has four main pillars: Piaget's (1896-1980) cognitive development, Vygotsky's (1896-1934) sociocultural theory, Bruner's (1915-2016) scaffolding theory, and Wertsch's (1988) mediated action theory. Piaget (1977) asserted that learning is an active construction of meaning by learners, influenced by their cognitive development stages. Vygotsky (1978) emphasised the importance of a socio-cultural context mediating learning through internalisations of cultural practice. Bruner's (1960) scaffolding theory highlighted the need to scaffold learning by a mentor who acts as an activator, motivator, and designer to provide well-designed social settings for increasing the effectiveness of learning. Wertsch's (1998) mediated action stated that agents negotiate with the tools they are using through a process of tool-equipped mediated action iteratively. This framework supports the study's investigation into the efficacy of traditional lectures and progressive active learning approaches such as problem-based learning (PBL), group-based learning, and learning by doing.

Progressive and Traditional Learning Approaches

Active learning encapsulates progressive learning approaches in biomedical engineering education by engaging students through problem-based, group-based, and experiential learning methods. Problem-based learning involves solving real-world problems collaboratively, enhancing critical thinking and problem-solving skills (Stanton & McCaffrey, 2010). Group-based learning promotes peer interaction and teamwork through small group activities (Jaques & Salmon, 2007). Learning by doing, such as prototyping, allows students to apply theoretical knowledge practically, fostering deeper understanding and retention (Christie & de Graaff, 2017;

Hart, 2024). These methods are beneficial in raising student interest and responsibility learning through problem-solving linked to the specific topics and projects (Vodovozov, 2021).

Traditional biomedical engineering pedagogy is principally based on two methods of transmission, laboratory classes and lectures. Both have persisted even though opportunities for transforming traditional pedagogies in Higher Education have existed for a considerable period. Lectures complemented by laboratory classes remain the standard and integral to engineering curriculum probably due to the value of putting theory into practice (Edward, 2002), while lectures are a practical and cost-effective solution for teaching large classes and income generation in universities (Dommett et al., 2019; Offstein & Chory, 2019). Lectures can be delivered via face-to-face, online recording, asynchronous online module, and synchronous livestreaming. These lecture modes are teacher-centred or technology-assisted to student learning. The main concern is that both the system and students can fail within the pedagogies when a surface learning approach instead of one that promotes deep learning is adopted (Christie & de Graff, 2017).

Method

This study adopted survey research, administered via *Qualtrics,* for gathering the perception of learning approaches from the 2022's cohort of biomedical engineering students between late June and July 2022 (Human Research Ethics Approval Number: HC220341). Out of a total of 575 students, 111 completed online questionnaires were collected (94 undergraduate and 17 postgraduate students). Three closed selection questions using three-point Likert scale, comprising positive, neutral and negative, out of the 25-question survey were analysed based on the proportions of the total sample size and chi-square tests for multiple proportions for checking significant difference (set at $p = 0.05$) between learning activities, lecture modes, and preferred learning styles. They aimed to answer two research questions: 1) what are student perceptions towards traditional and progressive pedagogy for biomedical engineering? and 2) what is the pedagogical direction in biomedical engineering education in the future?

Results

There are three main findings. First, progressive teaching methods including laboratory classes, prototyping and problem-based learning, were more preferred for learning than the traditional method, lecture, by 72% of the respondents ($p < 0.001$) (see Figure 1). Second, the traditional face-to-face lecture method (57%) was still the most preferred compared with other lecture modalities ($p = 0.0002$), possibly due to the direct and synchronous teacher-student interactions it can provide (see Figure 2). Lastly, a noteworthy finding of learning styles in this study is that learning individually (58%) is as favourable as collaborating in small groups (55%) among the respondents ($p < 0.001$), as indicated in Figure 3.

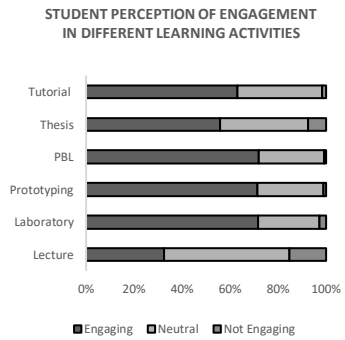

Figure 1. Student perception of engagement in different learning activities

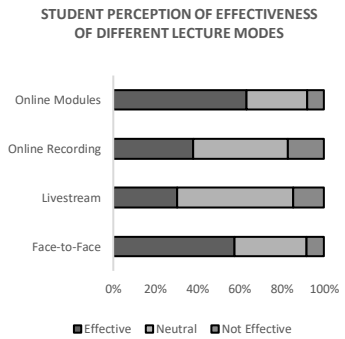

Figure 2. Student perception of effectiveness of different lectures modes

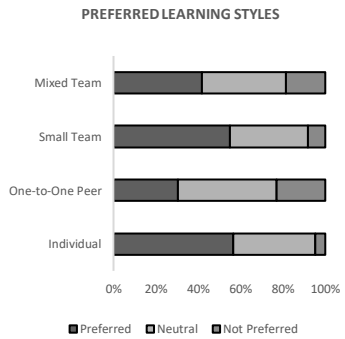

Figure 3. Preferred learning styles

Discussion

Progressive teaching methods were more preferrable for learning than the traditional method, lecture. Although laboratory classes are often classified as a traditional teaching approach in some literature (Christie & de Graaff, 2017), laboratory work typically involves students experimenting with their hands through learning by doing. It, thus, is an active learning method, similar to prototyping, and problem-based learning from this study's perspective. In particular, the active learning methods seek student active involvement and knowledge construction by putting theories into practice via laboratory work, prototyping, and problem-solving. However, scaffolding activities is crucial for meaningful and deeper learning because "it allows instructors to provide an optimal level of challenge by maintaining a balance between active engagement and nonproductive floundering" (Ertmer & Glazwski, 2019, p. 325). …

Despite the preference for progressive methods, traditional face-to-face lectures were still highly preferred. This could be attributed to the direct and synchronous teacher-student interactions they provide. From Vygotskian's perspective, the lecturing method provides the social setting and interaction that mediate student learning through intra- and inter-personal processes. Similarly, online lecture modules and recordings were equally preferred, possibly due to their temporal and location flexibility embedded in the technology. In other words, the online modules and recordings (tools) could sufficiently mediate the action of learning of this student group who felt that their expectations were being met and satisfied (Wertsch, 1988). Finally, livestream lectures were the least preferred because they fail to provide the synchronous teacher-student interaction experience resembling in-person lectures that is crucial for learning to happen through interpersonal processes due to delay or no responds to the virtue attendees (Vygotsky, 1978).

Lastly, individual learning was found to be as favourable as collaborative learning in small groups, different from Vidal's et al (2022) study showing that small group learning was more preferrable than individual learning by Spanish engineering students. On the one hand, small team, especially four-member composition, can best facilitate students identifying gaps in their own understanding and deepening their learning through the support of more able peers (Vygotsky, 1978). On the other hand, individual learning allows individuals to use the relevant culturally embedded tools as assistance to aid deeper learning according to their own pace (Wertsch, 1988).

Conclusions

This study's survey results have depicted a diverse perception of various pedagogies from progressive to traditional. Despite the rhetoric for increasingly online learning, biomedical engineering students still see traditional lectures as engaging and effective for their learning. The social aspect of learning that live lectures can facilitate, in contrast to livestreamed lectures, demonstrates the importance and function of interpersonal process embedded within the socio-cultural context is irreplaceable by impersonal teaching via technology. This highlights biomedical engineering educators must not lose sight of what creates an effective learning environment.

According to the findings, on the one hand, biomedical engineering students generally preferred more active learning driven approaches. On the other hand, there was a slightly higher preference for learning individually rather than collaboratively. This divergent view indicates a discrepancy between teaching and learning in biomedical engineering education. In other words, a clash between the concept of 'ideal' learning and 'accustomed' learning amongst biomedical engineering students.

To reconcile the different views, a systematic review on various of blending lectures with different active teaching approaches in universities, biomedical engineering education particularly as the first step to understanding the efficacy of mixing traditional and progressive pedagogies. This can couple with further

investigations on biomedical engineering students' understanding of ideal and accustomed learning methods/styles, and what constitutes such thoughts before exploring ways of building student capability of collaborative learning under an active learning pedagogy, such as problem-based learning within biomedical engineering education.

This study recommends future studies to include larger sample size and avoid multiple comparisons to increase statistical strength. Furthermore, parameters for measuring student perceptions such as engagement, and effectiveness should be clearly defined and provided in a survey as a data collection instrument for ensuring data validity.

Learning is as much a social endeavour as it is an academic one.

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