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Ensuring Student Active Engagement in Engineering Education

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Abstract. Active learning has been widely promoted in recent decades in higher education in various disciplines, including applied science fields such as engineering. Greater student engagement is considered by instructors to result in improved student learning. Instructors have introduced various activities to their classes to reduce or replace long lecture hours in an attempt to promote active learning. This requires students to engage deeper with content, both theoretical and practical. However, student engagement amounts to more than just physical activity, even though many instructors may be inclined to think otherwise. Physical activity, as indicated by student behavior, does not necessarily mean that knowledge construction has occurred. This results in less than optimum achievement of desirable learning outcomes and raises questions about the need to consider other engagement dimensions, including emotional, cognitive, and agentic, given that all of these connect with, and influence how humans learn and how the brain functions. Multidimensional engagement is crucial in stimulating and sustaining student engagement for effective learning. Through the lens of Transdisciplinarity, this paper relates multidimensional engagement to effective knowledge construction. It explains the connection that can be made between multidimensional engagement and experiential learning theory. It reports on how this has been applied in the teaching of engineering. The paper offers suggestions for promoting and maintaining multidimensional engagement, which would benefit the successful implementation of easy-to-implement and complex active learning methods and strategies in engineering education and beyond.

Keywords. Engagement, active learning, engineering education, human learning, experiential learning theory

Introduction

The way we understand how students learn has been changing as reflected in the progression of learning theories, from behaviorism and cognitivism to constructivism (Figure 1). Under constructivism – which emphasizes interaction and authentic learning experience, learning is viewed as a process where individuals construct their own knowledge and concepts by interacting with the world [1, 2]. Students are no longer recipients of knowledge. Since constructivism provides more practical paths for students to attain higher-order thinking skills [1], it has attracted attention from higher education, including applied science fields such as engineering. Many approaches have been

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developed to provide more constructivist learning experiences to students, including active learning methodologies.

Accordingly, student engagement during learning has become more critical. It has been the subject of much discussion as it has been used to refer to how involved or interested students appear to be in their learning. However, high student engagement can be hard to achieve, and many obstacles exist in fostering and sustaining it. Among them, the crucial one is many instructors still understand student engagement based on behaviorism – student behavior in physical activities. According to that, it has happened – based on our observations through a faculty development program in engineering and technology – that they plan, offer class activities, and observe student learning progress based solely on behavioral engagement rather than the other dimensions, such as cognitive and emotional engagement, that strongly contribute to effective knowledge construction.

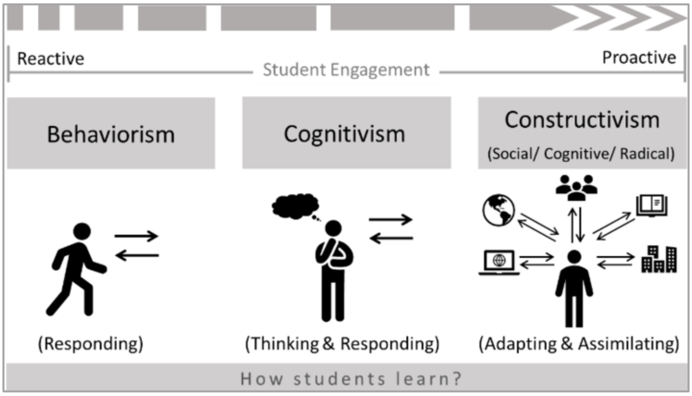

Figure 1. Student learning based on learning theories.

This paper offers a broader perspective on student engagement and provides a conceptual model to aid instructors in fostering student engagement within constructivist learning environments. The following sections provide a comprehensive view of student engagement, its multidimensional nature, and the obstacles to fostering and sustaining it. A conceptual model and its illustration in an engineering class are presented, followed by a discussion and conclusion.

1. Student engagement

1.1 Defining student engagement

Many current definitions of student engagement are institutionally focused, concerned predominantly with outcomes such as retention and success rates [3]. Other definitions focus on the extent to which students are engaging in activities that contribute to the required learning outcomes [4]. Zepke et al. [5] broadened their accepted definition to include a focus on the students' cognitive investment, active participation, and emotional commitment to their learning. A frequently-used definition is that provided by Schaufeli et al. [6]. "A multi-aspect construct that includes effort, resiliency, and persistence while facing obstacles (vigor), passion, inspiration, and pride in academic learning (dedication), and involvement in learning activities and tasks (absorption) as the main facets of this construct" (Schaufeli et al. [6], cited in Bowden et al. [7]).

Wimpenny and Savin-Baden [8] found student engagement could be classified as follows: engagement as connection and disjunction with the learning experience; inter-relational engagement (between students and others); engagement as autonomy (and self-sufficiency in learning); emotional engagement – illustrated by intrapersonal capacity, in terms of student resilience and persistence.

1.2 Importance of engagement

Higher education institutions conduct frequent surveys of student engagement, seen as a valid indicator of institutional excellence [9]. It is viewed as a key predictor of academic performance, persistence and retention in higher education. In their review of existing studies, Bowden et al. [7] report that student engagement has been linked to increased retention; enhanced institutional reputation [3]; increased citizenship behaviors; and work-readiness. It has also been linked to more subjective and holistic outcomes for students themselves including; social and personal growth and development; transformative learning; enhanced pride, inclusiveness and belonging; and student wellbeing.

1.3 Multidimensional nature of engagement

Many researchers now recognize the multidimensional nature of engagement, reporting four distinct, yet interrelated, aspects: academic, behavioral, cognitive and affective [10]. An earlier study by Fredricks et al. [11] proposes three dimensions: behavioral, emotional, and cognitive dimensions. Reeve and Tseng [12] posted a fourth type of engagement, which they call agentic engagement. This occurs when a student constructively contributes to the flow of instruction.

A similar categorization is used in a study by Bowden et al. [13] who reposition student engagement as consisting of four distinct yet interrelated dimensions, namely behavioral engagement, affective engagement, cognitive engagement and social engagement. Students may exhibit the four dimensions of engagement, simultaneously or in isolation.

The behavioral dimension relates to observable academic performance and participatory actions and activities [14,15]. Academic performance includes positive conduct, attendance, class participation, involvement in academic and co-curricular activities, and perseverance with challenging tasks [16].

The affective dimension of engagement relates to feelings of belongingness and relatedness [17]. It refers to emotional investment and the connection students feel towards their higher education experience [6]. This may be demonstrated through happiness, pride, delight, enthusiasm, openness, joy, elation and curiosity [16]. Emotionally engaged students are able to identify the purpose and meaning behind their academic tasks and social interactions [6].

The social dimension of engagement considers identity and belongingness between students and others [18]. This generates feelings of inclusivity, belonging, purpose, socialization and connection [19]. Within the classroom, it is associated with cooperation, active listening, punctuality and a balanced teacher–student power structure

[18]. Outside the classroom, social engagement is displayed through students' participation in campus activities [18].

Cognitive engagement refers to psychological investment in academic work, and interest paid to academic pursuits, for example, effort, purposiveness, strategy use, and self-regulation [5]. Students demonstrate this through their perceptions, beliefs, thought processing and strategies employed [20]. Cognitively engaged students are more likely to demonstrate higher order thinking [3].

Thus, engagement involves more than just participation in educational activities. Opting for a more multi-dimensional definition may help understand the student experience more completely, for example, explain the academic and social difficulties experienced when students transition to higher education [21]. Since difficulties in either of these areas can result in student dropout, a greater understanding of what leads to low cognitive and affective engagement is merited so as to inform best practice in higher education [22].

2. Obstacles to student engagement

There are various hurdles in ensuring optimum student engagement, which may be categorized according to three components constructing student learning experiences [23] – functional (the course content), humanics (the instructor's and students' performance) and mechanics (the settings and environments) – discussed below. These hurdles are encountered by HE providers, but also by students. In fact, the capacity of students to overcome hurdles or obstacles is itself a measure of the quality of their engagement, as alluded to in the definition of student engagement quoted earlier in the paper i.e., 'a multi-aspect construct that includes effort, resiliency, and persistence while facing obstacles…' (Schaufeli et al. [6], cited in Bowden et al. [7]).

2.1 Functional components

The alignment between student expectations and course offerings is a major factor in ensuring student engagement. Learning outcomes may be considered too demanding or too basic by students, resulting in low levels of motivation. Students may not see the relevance of the material for their academic and professional goals. Instructors may be relying on material that has been used successively in previous years, and not undertaken the required revisions to ensure relevance for the needs of current students. Among the obstacles reported by Crabtree et al. [24] are lack of resources, operational issues, staff buy-in, centralized structures and dis-jointed systems. Based on academic and professional staff opinions, this study also reports tensions regarding strategic versus operational issues and lack of coordination between professional services and academic departments. The study argues for senior leadership involvement, student engagement, strategic planning and mapping of the student journey.

2.2 Humanics components

Instructors may themselves be dealing with personal and professional issues that hinder their performance, for example, insecure tenure, inadequate preparation, apathy, low levels of motivation. Difficulties with classroom management, as well as inadequate mastery of pedagogical methods and academic content may also be a factor. Their preferred teaching style may not be appropriate for the class size involved or the student profile, particularly in cases where the class includes students who may have additional needs beyond those that the instructor may have usually encountered. The need to cater for greater diversity, such as captured in approaches like Universal Design of Learning (UDL) may not have been given due attention in the program design and delivery.

Increased participation and greater diversity among the student population means that approaches that proved successful for lecturers previously may no longer be so. The rise in the representant of 'non-traditional students' means there are increasingly students who are first from their families to attend college. This can also include mature students, students with disabilities and learning difficulties, students from low-income families and minority ethnic groups. Also at issue is the increased participation of part-time students, who may have significant other commitments, which may hinder their engagement. Student mobility and the growth of international students adds to the complexity.

2.3 Mechanics components

Student engagement may also be hindered by structural issues relating to physical infrastructure, which may be more conducive to more traditional forms of delivery. For example, collaborative group work requires flexible seating arrangement that may not be feasible in traditional lecture theatres. Timetabling issues, whereby students are timetabled at either end of the day or close to weekends may also impact negatively on attendance and participation.

Online delivery methods pose challenges that differ with those encountered in face-to-face contact. For example, instructors may have limited skills in engaging students in online collaboration and may be relying unduly on methods more suited to traditional face-to-face teaching. This can contribute to feelings of isolation, low levels of social engagement, difficulty in managing the transition to university and the ability to balance academic work and personal life. There are also challenges related to fitting in to the university 'culture' and developing a 'sense of belonging'. Other problems relate to student mental wellbeing, particularly post-pandemic as a result of the disruption to their educational participation.

3. Stimulating multidimensional engagement for effective learning

Based on the multidimensional perspective presented by Bowden and colleagues in 2017 [13], we proposed a hierarchical model of student involvement (Figure 2) to categorize different engagement levels that may occur when class activities progress toward constructivism. Within class activity, emotional engagement is more fit to the context than affective engagement, which contains a broader view. In the hierarchy, each level refers to the primary characteristic students possess at a particular time when engaging in an activity, which may partially subsume other dimensions. Social engagement is the lowest level, referring to a scenario in which students present themselves in a class

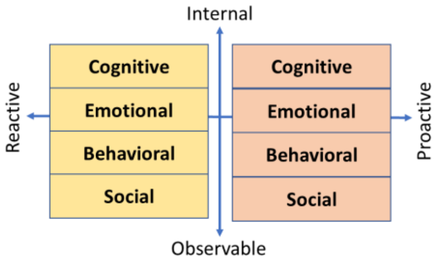

Figure 2. A hierarchical model of student engagement.

activity. Unlike social and behavioral engagement, emotional and cognitive engagement are difficult to observe. For example, students may or may not display their deep feelings in class.

According to cognitive neuroscience, changes in thinking and behavior are the outcomes of physical changes that occur in networks of neurons in the neocortex [26, 27]. This process happens when an elaborative rehearsal strategy – a transferring process of information from short-term to long-term memory through thinking and actions [2] – is properly implemented. Such high cognitive engagement includes epistemic cognition, metacognition, engagement with scientific and engineering practices, and reflection [25]. However, this process is challenging to materialize in classes because the high cognitive engagement is, in most cases, unobservable. High student engagement in learning is achieved gradually. Savin-Baden [28] notes that at the initial stages, students favor methods that do not require personal initiative or critical thought, but at a later stage, prefer autonomy and opportunity for reflection.

Therefore, planning constructivist activities is required to facilitate student engagement in order to reflect this progression. In this regard, we propose a conceptual model (Figure 3) based on Kolb's experiential learning cycle [29] to aid in engaging with constructivist activities.

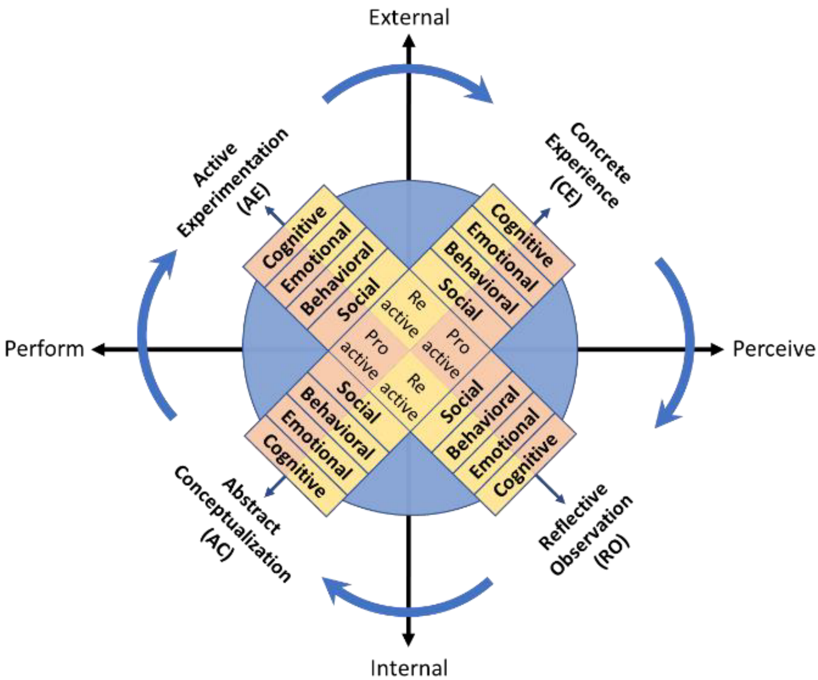

Figure 3. Conceptual model – student engagement in Kolb's experiential learning cycle.

The cycle has been proven to support how the neocortex functions and the implementation of the elaborative rehearsal strategy [26, 27]. The cycle was developed to transform the gained experiences to construct knowledge and develop expected capabilities. Learner engagement with these four sequential experiential stages allows them to be fully involved in new experiences (concrete experience - CE), critically reflect on the observed experiences (reflective observation - RO), logically develop their own concept (abstract conceptualization - AC), and attempt to solve a problem using the developed concept (active experiment - AE). This leads to new experiences with which the next learning cycle may begin. The transformation process can begin at any stage but is only completed when the cycle is closed. This four-stage learning cycle is an endlessly recurring process for learners to exchange between the learner's internal world and external environment. This results in improved learning over successive cycles. An illustration of this proposed conceptual model is presented in the following section.

4. Illustration of the model for teaching in engineering

The proposed model was used to plan teaching and learning activities for several topics of Additive Manufacturing and Reverse Engineering, a graduate course offered in the Industrial and Manufacturing Engineering program at the Asian Institute of Technology. Figure 4 presents the ten planned class activities for the 'Solid-Based Rapid Prototyping Systems' topic and the expected engagement level for each individual activity. The aim was to foster high student engagement within the constructivist classroom and aid students in developing their understanding of the topic.

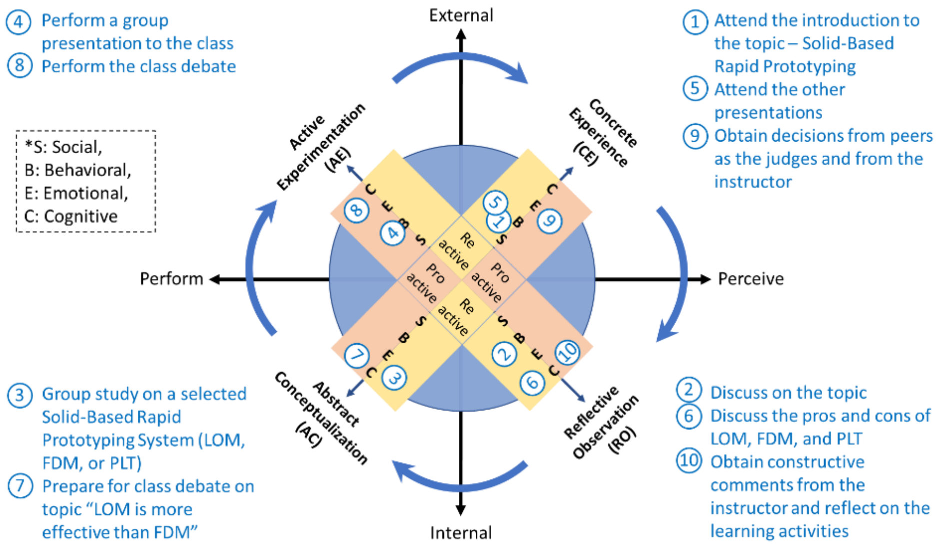

Figure 4. Illustration of planned activities in Additive Manufacturing and Reverse Engineering class.

The ten activities were planned to progress students from being reactive to proactive in class gradually, and to guide them through the completion of at least two consecutive learning cycles. In the first cycle (activities 1-4), their engagement begins at the social level when they attend and begin to interact with the topic content (1). In this session, the instructor presents the topic's background, importance, and key principles and attempts to connect students to the topic. The discussion then progresses their engagement to the next level (2). Here, they are asked to respond to a set of general questions posed to the whole class that supports their thinking and enquiry regarding different Solid-Based Rapid Prototyping Systems – Laminated Object Manufacturing (LOM), Fused Decomposition Modelling (FDM), Paper Lamination Technology (PLT) – providing paths to explore and research with their team in the next activity (3). Within 1.5 hours, they are expected to be able to present the complete view of the selected system to the class (4). The resulting, thinking, researching, reasoning, and collaboration within the team fosters epistemic cognition and engagement to the high level. However, the actual level of their engagement is reflected in the depth of their presentation to the class and their responses to peer contributions and questions.

In the second cycle, the experiences students gained from attending peers' presentations (5) plus their current understandings constitute the sources needed for engagement in the following class discussion. For this discussion, engagement is expected at a high level. All individuals are expected to use active listening, communication, and higher-order thinking skills to respond to peer enquiries, and to discuss and differentiate the systems from different angles (6). This includes any misconceptions and misunderstandings that may need to be clarified. However, instead of simply providing the correct response, the instructor directs student attention to their misunderstandings and misconceptions and encourages them to explore and acquire the needed information. To do so, the instructor assigns the class to prepare for the debate (7). The teams that studied LOM and FDM are designated the Pro and Con teams, and the other team is given the role of judge. From this point, students are obliged to take on a proactive role, becoming fully in charge of their own learning and independent of the instructor's guidance. They collaborate with the team, discuss, and practice research skills – gathering, analyzing, and interpreting information – to clarify any misconceptions and misunderstandings. They also need to develop a strategy to win the debate. Performing the class debate (8) and obtaining a favorable judgement (9) strongly activates their emotional and cognitive engagement. However, in the end, it is the instructor's role to provide constructive comments on the clarifications made during the debate and direct them to reflect on their learning experiences (10).

5. Discussion

The foreseen challenge of using this model – regardless of stages in the cycle and the nature of planned activities – is associated with student characteristics, which also play an important role in their engagement capability. For example, Sinatra and colleagues [25] report that students with high emotional intelligence possess greater capability to extend their emotional and cognitive engagement.

The proposed model reflects the importance of the multidimensional perspective of student engagement and the need to plan deliberately to support student learning. Planning class activities with the experiential learning cycle provides students with proper space and time to reflect on the learning experience, construct their knowledge, exhibit, test their concepts/understandings, consider feedback, and enable continued exploration and learning. This continual process reinforces the adoption of an elaborative rehearsal strategy in the student's long-term memory, thereby sustaining and expanding their understanding. It also allows the instructor to systematically monitor and gauge student engagement levels – which are multifaceted and comprise dimensions that are not easily observable – and assess student learning progress.

Without such an experiential learning cycle, the risk is that students have limited opportunity to reflect and develop their understanding. This promotes a more superficial engagement with content. In such cases, students may exhibit certain behavioral and emotional engagement but their cognitive engagement remains less than optimum.

6. Conclusions

The problems encountered in optimizing student engagement provide the context for the development of the conceptual model just presented. The model is based on an understanding of multidimensional engagement and is designed to assist instructors in planning for and achieving greater outcomes through active student learning. The illustration provides a practical perspective of the model. It amplifies a call for dedicated consideration to expand the view beyond behavioral and emotional engagement when attempting to apply active – whether they are easy-to-implement or more complex – learning methods in their classes.

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