

# Problem-based learning as an assessment: Enhancing students' connective learning and constructive learning

Shanta Dutta • Mingjing He • Daniel C.W. Tsang\*

Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China.

\*Corresponding author. E-mail: dan.tsang@polyu.edu.hk; Phone: +852- 27666072.

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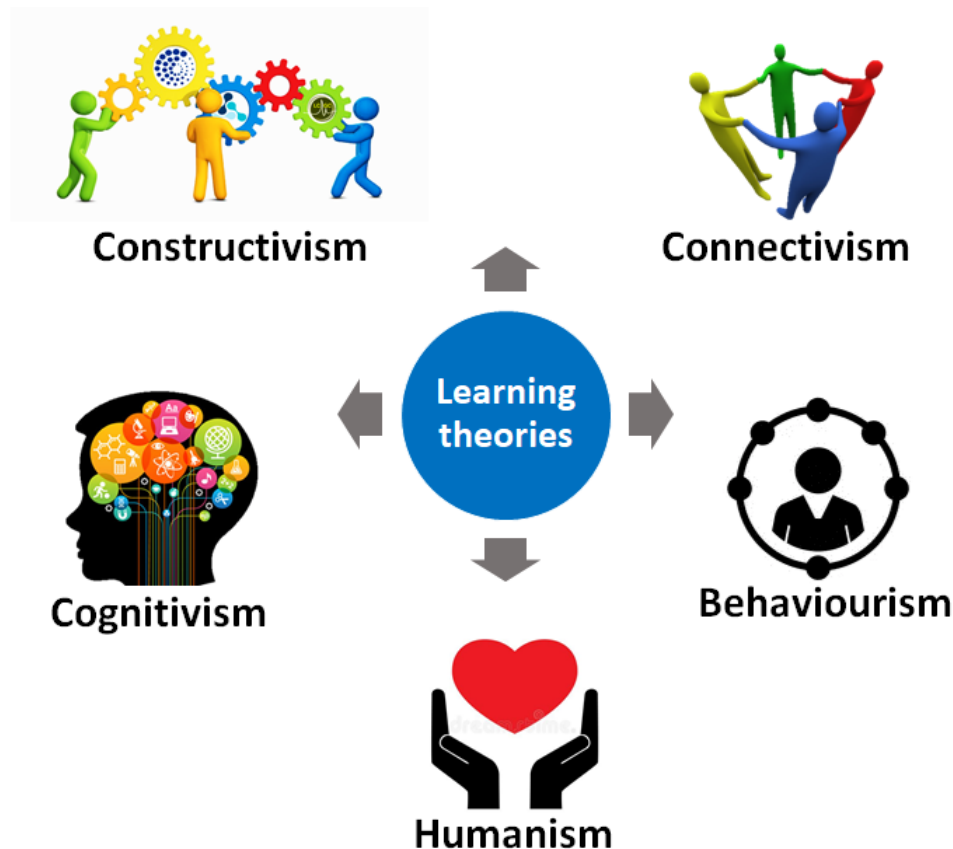
**Abstract.** For the sake of enhancing students' broad knowledge, problem-solving skills, and professional competences, this educational research project implemented problem-based learning (PBL) as a pedagogic tool in a large-class setting with 154 students involved at The Hong Kong Polytechnic University. The students participated in a problem-solving task that accounted for 25% of their course assessment (summative), which was designed with complex scenarios similar to real-life circumstances. The PBL assessment was structured in a way that required students' efforts to explore and connect relevant ideas supplemented with verifiable study materials, and a guided learning environment was provided by the course instructor and tutors. Learning activities were tailored to foster students' active engagement and self-directed learning attitude towards resolving the PBL assessment. To evaluate the performance of the PBL approach, pre-and post-test questionnaire surveys were conducted to understand the improvement of students' confidence regarding their learning ability, knowledge building, critical thinking, skill transfer, etc. The findings of these surveys revealed that the PBL assessment and related learning activities successfully stimulated students' self-directed learning behaviour, enhanced their collaboration among peers, and expanded their capacity to develop critical skills for complex problem-solving tasks. Despite a challenging online learning environment compared to traditional classroom settings owing to the pandemic situation, the students considered this PBL assessment with guidance by the course instructor and tutors as creative, exciting, and very effective for life-long skill development. This research highlighted great prospects regarding implementing PBL approaches, even as an assessment component, in higher education institutions, which could be highly beneficial for nurturing competent graduates with essential practice-oriented skills and self-directed learning behaviour.

**Keywords:** Higher Education, Scholarship of Teaching and Learning (SoTL), Learning Theories, Teaching Pedagogy, Constructivism, Connectivism.

## INTRODUCTION

The teaching and learning environment could be critical in shaping students' knowledge, skills, and prospective careers. Complex situations in real workplace settings require desirable graduates to tackle different problems and issues, which are posing grand challenges and emerging needs for an innovative higher education curriculum (Nowell *et al.*, 2020). To meet global standards, universities are continuously updating teaching resources and learning activities. However, different pre-university systems create a global challenge that often requires fine

adjustment of the practices of teaching and learning to accommodate diverse student needs. To develop a progressive higher education system that can nurture skilled graduates/professionals, constant transformation of teaching practices and learning activities would be necessary, including innovative pedagogical approaches, student-teacher relationships, students' engagement in learning, commitment to self-directed learning, technical and social skill development, etc. (Tikhonova and Raitskaya, 2018).



**Figure 1.** Major learning theories involving diverse dimensions.

To understand the effectiveness of pedagogical approaches, evidences can be drawn from the scholarship of teaching and learning (SoTL) (Wong, 2012). SoTL refers to a systematic investigation of students' learning aimed at advancing the practice of teaching in higher education. SoTL is a particular kind of educational research that explores pedagogy, teaching practices, and all relevant aspects of students' learning and engagement, which can help teachers make teaching and learning more effective. "Scholarship of teaching and learning is work that encourages an empirical examination of teaching in relation to student learning. It is distinct from scholarly teaching in that it goes beyond teaching well, even superbly, to participating in a focused inquiry process and reflective practice about one's own teaching" (Darling, 2003). The SoTL platform encourages teachers to conduct teaching and learning research for advancing theories and practices, thereby creating added values in higher education.

Problem-based learning (PBL) as a pedagogical approach has been widely adopted in educational institutions covering diverse fields and learning contexts to bridge the gaps between conventional classroom settings and complex scenarios in real workplaces and situations. PBL has considerably encouraged researchers to

investigate its influence on students' learning enhancement and problem-solving skill development (Yew and Goh, 2016). To ensure students' effective learning and comprehensive understanding of the subject of interest, various learning theories can be dynamically adopted under the PBL approach. For instance, constructive learning and connective learning (Figure 1) can be applied together to augment the overall learning process, which would be highly beneficial for students.

### **The context of problem-based learning assessment**

PBL is a student-centric pedagogical approach in which students engage themselves in an active learning process through solving meaningful and real-life problems, thereby promoting their self-directed learning. Compared to traditional instructor-centred and lecture-based learning environments, PBL can be more stimulating in enhancing students' understanding and learning ability through their active engagement (Yiu *et al.*, 2021). Interactive and situation-oriented activities designed for PBL can increase the opportunities for communication and collaboration among students, which might help develop their future careers (Tsang *et al.*, 2018). Typically, learning is initiated

through a problem that requires resolution and work in collaborative groups to solve the problem. “Problem-based learning (PBL) is an instructional method in which students learn through facilitated problem solving. In PBL, student learning centers on a complex problem that does not have a single correct answer. Students work in collaborative groups to identify what they need to learn in order to solve a problem. They engage in self-directed learning (SDL) and then apply their new knowledge to the problem and reflect on what they learned and the effectiveness of the strategies employed. The teacher acts to facilitate the learning process rather than to provide knowledge.” (Hmelo-Silver, 2004). Therefore, constructing an appropriate problem with realistic, complex, and ill-structured scenarios would be necessary to trigger students’ curiosity for progressive learning. With minimal guidance from teachers who usually act as a facilitator, students get involved in self-directed learning and individual research to identify the knowledge gaps with respect to the concerned problem. The PBL approach might be advantageous in increasing students’ motivation, critical thinking skills, and problem-solving skills. “The final goal of PBL is to help students become intrinsically motivated. Intrinsic motivation occurs when learners work on a task motivated by their own interests, challenges, or sense of satisfaction.” (Hmelo-Silver, 2004).

### **Constructive learning**

PBL is principally designed to cater to the learning style under constructivism. “The principle of constructivism positions students as active knowledge seekers and co-creators who organise new relevant experiences into personal mental representations or schemata with the help of prior knowledge.” (Yew and Goh, 2016). The theory of constructivism implies that the learning process is personal and individual, and students create their own learning based on past experiences. “Constructivists believe that knowledge is essentially subjective in nature, constructed from our perceptions and mutually agreed upon conventions. According to this view, we construct new knowledge rather than simply acquire it via memorisation or through transmission from those who know to those who don’t know.” (Bates, 2019). Constructivism suggests that the learning process is contextual, and the learner and learning environment are both critical factors for constructive learning (Jonassen, 1991). This learning style stresses the flexible use of pre-existing knowledge rather than recalling pre-packaged schemas. Constructive learning encourages students to apply their learning to the real world, thereby creating meaning and understanding through experiences, and they develop interpretations of the external world based on individual experiences and interactions. Hence, the actual learning experience should be inspected to evaluate the learning which occurred within an individual (Bednar *et al.*, 1991).

In a constructivist classroom setting, teachers act as a guide to help students create their own learning and understanding (Ertmer and Newby, 2013). Constructivist teachers place a high importance on students developing personal meaning through reflection, analysis, and gradual building of knowledge that involves mindful and constant learning. “The level of teacher guidance can vary in a constructivist approach to problem-solving, from none at all, to providing some guidelines on how to solve the problem, to directing students to possible sources of information that may be relevant to solving that problem, to getting students to brainstorm particular solutions.” (Bates, 2019). Assessments in the constructive learning environment focus on the transfer of knowledge and skills, which often involves presenting new problems and situations that differ from the conditions of the initial instruction.

### **Connective learning**

Connective learning is based on the concept of distributive knowledge. The theory of connectivism implies that knowledge is a network of ideas and learning is a process of connecting specialized nodes or information sources. The connective learning style puts an emphasis on developing the skills to connect, build and expand networks, and identify knowledge gaps. “Learning in connectivism terms is a network phenomenon, influenced, aided, and enhanced by socialization, technology, diversity, the strength of ties, and context of occurrence.” (Tschofen and Mackness, 2012). During the connective learning process, teachers need to provide a guided learning environment with verified materials and learning resources for students to discuss with their peers. However, effective learning outcomes often depend on the capacity and skills of students to connect ideas and build relevant knowledge, and the capacity to learn is more critical than what is currently known. “Connectivism is driven by the understanding that decisions are based on rapidly altering foundations. New information is continually being acquired. The ability to draw distinctions between important and unimportant information is vital. The ability to recognize when new information alters the landscape based on decisions made yesterday is also critical.” (Siemens, 2017). Therefore, connectivist learning activities should be appropriately designed to ensure accurate and up-to-date knowledge for the students.

### **Study scope**

This SoTL project implemented PBL as a pedagogic tool to enhance students’ learning in a large-class setting at The Hong Kong Polytechnic University, China. Learning outcomes in the subject were evaluated through a problem-based assignment that was counted as 25% of the course assessment for all students. To foster students’

engagement, collaboration, and lifelong skill development, the PBL assessment was structured and aligned with the theory of constructivism and connectivism explained earlier in this section. Learning activities were designed to help the students develop a self-directed learning attitude and to enhance the quality of their learning by co-creating an effective learning environment. Learning attitudes and experiences of the students were carefully observed and evaluated by questionnaires to quantify the effectiveness of the PBL approach through pre-and post-questionnaire surveys. Furthermore, students' feedback and reflections on the PBL assessment and overall learning experiences were recognized, which were beneficial to gauge the effectiveness of PBL in both quantitative and qualitative manners.

## **MATERIALS AND METHODS**

### **Student engagement in the problem-based learning assessment**

The PBL assessment was implemented in a large-class setting at The Hong Kong Polytechnic University (PolyU) under the course "CSE30337 - Water and Waste Management" with 154 full-time undergraduate students (2 students in one group, 77 groups in total). The PBL assessment was summative in nature and contributed to 25% of the course assessment, which was designed to motivate the involved students toward their self-directed learning based on the learning theories under constructivism and connectivism. Based on the introductory knowledge and guidance given by the course instructor and tutors during lectures, the students were stimulated to actively engage in the self-directed learning process by conducting individual research as well as exchanging ideas and knowledge with their peers. They were involved in constructive and connective learning activities and stimulated to develop skills for building and expanding networks of ideas, which were necessary to identify and fill in the knowledge gaps regarding the concerned problem and to eventually formulate a feasible solution.

Two open questions were given for each group, including: (i) Under the pandemic situation, single-use plastics are substantially used and dumped after each meal. Discuss the impacts on the natural environment and the need for future waste treatment facilities; and (ii) Antibiotics are extensively used nowadays in livestock farming and urban areas. Discuss the impacts on conventional wastewater treatment facilities and the need for future treatment designs. The students' performance was assessed in the form of 15-min group presentation video, which was graded against the mutually agreed assessment rubrics by considering the technical contents (i.e., introduction, application of engineering knowledge, evaluation of engineering solutions, and conclusions; representing 80% of assessment) and presentation skills

(i.e., coherence, clarity, and engagement; representing 20% of assessment).

### **Questionnaire survey for performance evaluation**

Pre- and post-test questionnaire surveys were conducted among participating students on a voluntary basis to self-assess their learning experiences and solicit their feedback before and after the PBL test (1-month time frame). There were 273 completed surveys in total collected from students including 144 pre-test and 129 post-test surveys for data analysis. The pre-test questionnaire included quantitative elements only, whereas the post-test questionnaire also included a section of open-ended questions (i.e., qualitative elements) apart from the quantitative sections. The questionnaire survey was designed carefully to align with the principles of learning theories for constructivism and connectivism, with a total of ten specific questions (Figure 2). Among them, questions one to five (Q.1-5) were designed to evaluate students' learning attributes before and after attending the course assessment focusing on constructivism. In contrast, questions six to ten (Q.6-10) were designed in a similar manner aligned with connectivism. Students were asked to self-assess and rate their confidence in response to the specific questions on a scale of 1 to 7, where 1 means "Not Confident", 4 means "Neutral", and 7 means "Very Confident". A mean score was calculated for each question (pre- and post-test) to quantify the efficacy of the PBL approach adopted in this study.

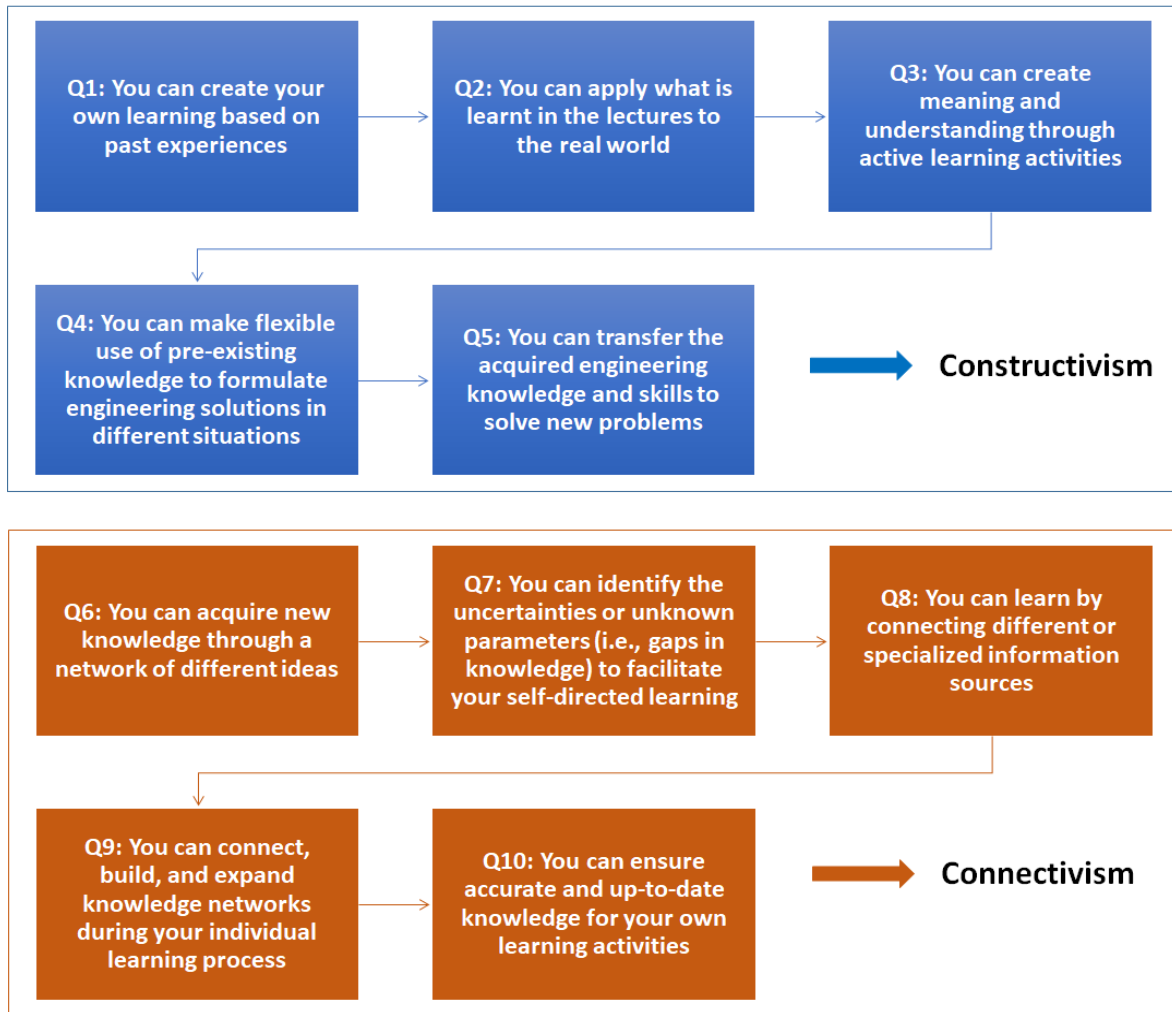
### **Post-assessment feedback and reflection**

At the end of the assessment, students were asked to reflect on their learning experiences and provide feedback regarding their understanding and observations during preparation and assessment. Five questions were designed to facilitate the feedback collection procedure (Table 1) and included in the post-test questionnaire. Following the process mentioned earlier, students were requested to rate their feedback in response to the specified questions on a scale of 1 to 7, where 1 means "Not Confident", 4 means "Neutral", and 7 means "Very Confident". A mean score was calculated for each question included for comparing the feedback. An open-ended section was included in the post-test questionnaire where students were encouraged to share their reflections and comments regarding the assessment, and provide suggestions if any to improve the teaching and learning process through the PBL approach.

## **RESULTS AND DISCUSSION**

### **Students' learning attributes before and after the assessment**

As revealed by the results of the questionnaire survey



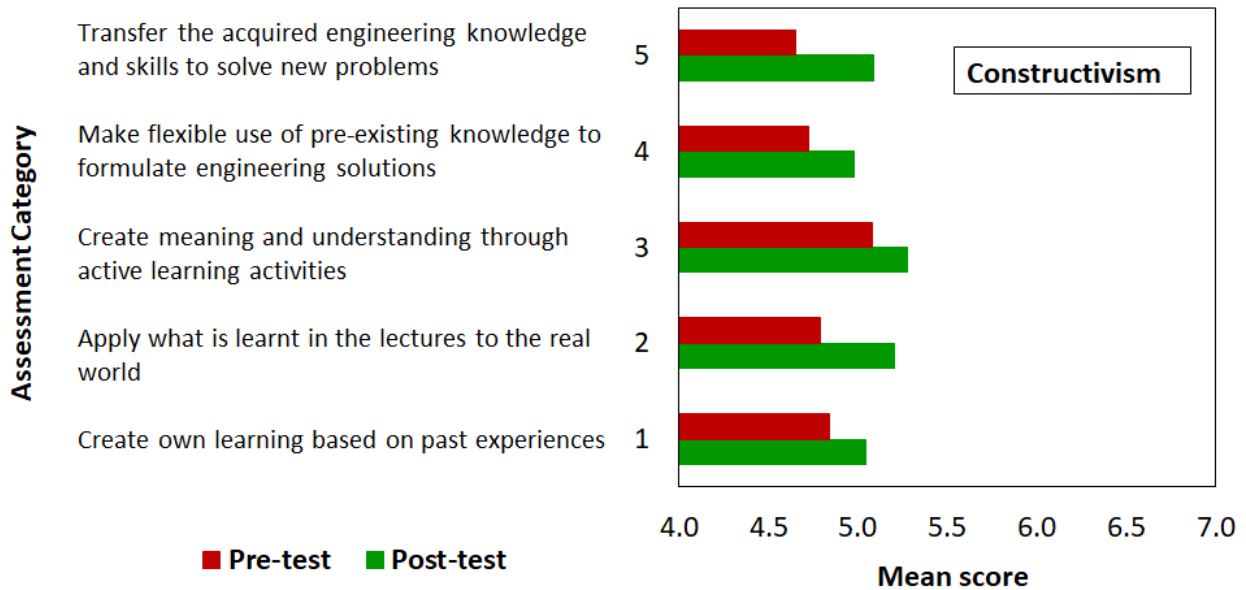
**Figure 2.** Pre- and post-test questions for evaluating self-assessment of professional knowledge.

**Table 1.** Questions for post-test feedback collection regarding problem-based learning.

No.	Question
Q11	You can develop a deep understanding and higher-order thinking skills of critical thinking and problem solving, etc.
Q12	You can solve ill-defined, real-life problems through a wide range of activities
Q13	You can make use of different online and library resources to solve engineering problems in the real-world situation
Q14	You can engage in self-directed learning activities to acquire new knowledge
Q15	Problem-based learning as a course assessment is appropriate for developing your professional competence and generic abilities
Q16	Please give your suggestions/comments on this subject

(Figure 3), the students demonstrated a strong agreement regarding their enhanced learning attributes after

completing the PBL assessment. The mean scores for questions in different categories generally increased



**Figure 3.** Comparative scores for pre-and post-test questionnaire survey reflecting students' enhancement through problem-based learning following the principles of constructivism.

during the post-test questionnaire survey compared to the pre-test ones. Students' mean scores on the pre-test questionnaire ranged from 4.7 to 5.1, while the mean scores on the post-test questionnaire ranged from 5.0 to 5.4, which were notably higher than their pre-test level. A higher mean score in the post-test survey indicated that the PBL approach was effective in nurturing students' self-directed learning attitude and improving their overall learning process. It is encouraging to confirm that the students were able to enhance their professional knowledge through the PBL assessment, which reflected the practicality and efficacy of the PBL approach in the large-class setting.

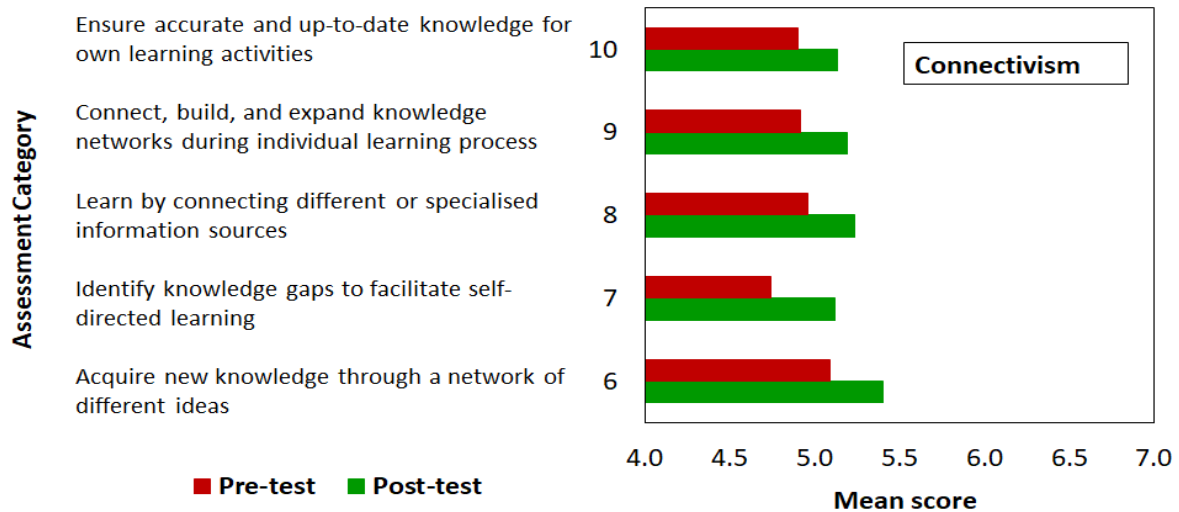
Valuable perspectives regarding the students' learning attributes could be revealed after reviewing the differences in mean scores for individual questions specifically designed in alignment with the principles of constructivism and connectivism. Concerning the constructive learning approach applied during the assessment, the students were able to create their own learning based on past experiences (Q-1) (Figure 3) in a way better after completing the PBL assessment, which could be considered the most fundamental basis for enhanced learning under the constructivist learning theory. The students particularly demonstrated a strong agreement for their improvement when asked if they could apply what is learned in the lectures to the real world (Q-2). The mean scores for Q-2 increased by 8.6% (Figure 3) end of the assessment suggesting that the PBL assessment stimulated students' endeavour to develop the necessary skills to tackle complex issues similar to those could exist in real-life situations. Another crucial indicator of the efficacy of PBL was the capability of students to transfer

the acquired knowledge and skills to solve new problems (Q-5). In this context, the students' mean scores demonstrated the most significant improvement under the constructive learning approach (9.3%) when comparing the pre-and post-test questionnaire surveys. This result is very promising and suggests that the PBL assessment could aspire the students to become proactive, independent learners, and apply their acquired knowledge for problem-solving. Moreover, the students could effectively create meaning and understanding through active learning activities (Q-3, mean score increased by 4%), and made flexible use of pre-existing knowledge to formulate engineering solutions (Q-4, mean score increased by 5.4%).

The observed enhancement in all categories suggested that the constructive learning environment considerably enhanced students' learning ability and motivated them to develop their critical thinking and problem-solving skills required for prospective careers and real-life situations. These positive results achieved following the constructive learning approach affirmed that the PBL assessment could be appropriately designed including complex, realistic, and ill-structured scenarios, for promoting the students' active engagement. Outcomes in this study are in line with a recent study of Croy (2018), where a summative assessment designed utilizing a constructive alignment theory promoted effective teaching and deeper learning for the students. In this study, constructive learning experiences inspired the students and offered them a suitable context through which they could relate to the complex problems and apply their pre-existing knowledge to formulate the solutions required.

Comparative questionnaire surveys further revealed the





**Figure 4.** Comparative scores for pre-and post-test questionnaire survey reflecting students' enhancement through problem-based learning following the principles of connectivism.

students' confidence regarding their improved learning attributes, which were evaluated under the connectivist learning approach. In this context, the differences in mean scores between pre-and post-test questionnaires showed an increase in students' learning enhancement ranging from 4.7 to 8% (Figure 4). The students demonstrated a strong agreement when asked if they could acquire new knowledge through a network of different ideas (Q-6, mean score increased by 6.1%), and it was the most essential indicator to gauge the effectiveness of students' connective learning. In this rapidly changing era of information, there is an increasing trend that people tend to learn from trusted networks consisting of peers, professionals, and external experts, as knowledge can be distributed across connections and networks (Dabbagh and Kitsantas, 2012; Leone, 2013). Therefore, pedagogic approaches aligned with the principles of connected, distributed, and networked knowledge could be a way forward to the attainment of intended learning outcomes and desirable skill development (Corbett and Spinello, 2020), which was reflected by the increased mean scores of Q-9. In addition, a considerable increase in mean score was observed after completing the PBL assessment, where the students could identify knowledge gaps to facilitate their self-directed learning (Q-7, 8% increase in mean score). These findings indicated that the PBL assessment also successfully initiated students' connective learning and enabled them to explore and connect relevant knowledge and ideas required for solving the complex problems through peer interactions.

### Students' feedback and reflection regarding problem-based learning

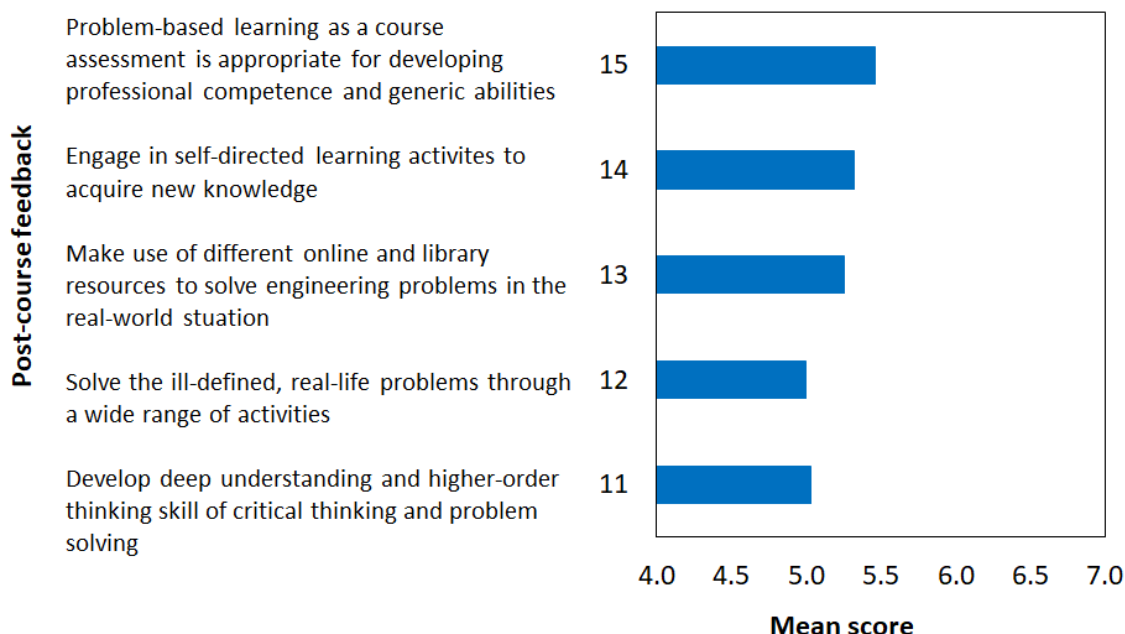
Reflecting on learning experiences, problem-solving,

knowledge building, and skill development are crucial components of the PBL system. Reflections help both teachers and learners to better comprehend the learning process and further act on their resolutions. "The reflection process in PBL is designed to help students make these inferences; identify gaps in their thinking; and transfer their problem-solving strategies, self-directed learning strategies, and knowledge to new situations." (Hmelo-Silver, 2004). Evaluating students' feedback provided a quantitative determination of the effectiveness of the PBL approach. In contrast, the open-ended section concerning reflection included in the post-test questionnaire provoked the students to ponder upon their learning attributes regarding the PBL assessment, consolidate relevant knowledge, and prompt them to think beyond their learning process.

### Students' feedback

This SoTL study collected students' feedback end of the PBL assessment to evaluate the effectiveness of students' learning quantitatively. The questions for post-test feedback were intended to encourage students to conduct a self-evaluation based on their involvement, understanding, and skill development through this PBL assessment and learning experience. The students who participated in this research mostly provided positive feedback regarding their learning experience. The mean scores for post-test feedback ranged approximately from 5 to 5.5, which was promising and re-confirmed the effective implementation of PBL in a large-class setting (Figure 5).

According to the students' feedback, the PBL assessment was considerably effective in developing a deep understanding and higher-order thinking skills of critical thinking and problem-solving (mean score: 5) (Figure 5). A wide range of activities involved in the



**Figure 5.** Mean scores showing student feedback regarding problem-based learning.

learning assessment enabled them to solve ill-defined, real-life problems (mean score: 5). To solve engineering problems similar to a real-world situation, they could make use of different online and library resources (mean score: 5.3). During the learning process, the students could engage themselves in self-directed learning activities which helped them to acquire new knowledge in the field of interest (mean score: 5.3). Furthermore, the students strongly agreed that PBL as a course assessment is appropriate for developing professional competence and generic abilities (mean score: 5.5). Previous studies indicated that constructive, collaborative, contextual, and self-directed learning principles led to higher student satisfaction and skill development compared to conventional methods of teaching (Bergman *et al.*, 2013; Luxton-Reilly and Denny, 2010). Affirmative feedback from the students in this study substantiates the effectiveness of the applied PBL approach, which can be further incorporated in future course design of higher education institutes.

### **Students' reflection**

The students shared their views and thoughts regarding their experience in this PBL assessment. They described their learning experiences as good, fun, realistic, and also beneficial for their prospective careers. Several students commented that the content and structure of the assessment were very interactive and the learning process highly stimulated their eagerness to learn more about the current practices and innovations in the field of interest.

For instance, a student remarked, "This assessment allowed us as students to engage in more real-life examples and methods of obtaining information". They appreciated the interactive exercises and discussion sessions where they could exchange their ideas and opinions about relevant topics as well as learning experiences. The majority of the students found the problem-solving assignment interesting and creative. Most of them preferred such an innovative and useful way of learning and testing their progress instead of answering exam papers. The students also revealed that the assignment made them review lecture notes more carefully and search for additional information from the library and online resources. Some interesting and useful remarks from the involved students are quoted as reference below.

"The mid-term test was conducted through problem-based learning with a video presentation. It helped me to analyze daily life problems that may cause impacts on the environment. It was a valuable experience for me."

"It was good for me to learn more real-life questions and problems by doing this test."

"I think it was a funny and interesting way to do the midterm through a video presentation."

"The midterm test was very useful for me developing the ability to identify engineering problems, it would be beneficial if more problem-based learning assignments are given."

"It was a good experience to explore new things from the internet and academic papers."

"I think the assignment and test arranged by our course instructor can truly motivate the students to learn the



subject, at the same time, the test/assignment was progressive which makes students who are new to this discipline comprehend the knowledge easily.”

“This subject allowed us as students to engage in more real-life examples and methods of obtaining information.”

“It was new to me to have a presentation rather than testing with pen and paper, this kind of mid-term test was less intense and good for me to prepare for the mid-term test.”

“It was fruitful for arranging mid-term test into a video presentation, which allowed me to enhance my problem-solving skills and communication skills.”

“Our course instructor was very inspiring and good at explaining things. He taught a lot of practical knowledge and also showed a lot of videos that demonstrated what he discussed, which was very helpful in understanding the subject easily.”

“Although making a presentation video was quite time-consuming, it was a good experience for me to learn real-life problems that I may face in my future work.”

As observed from the students’ feedback and reflections, they were intrinsically motivated by the PBL assessment. The opportunity to engage in a realistic problem and develop problem-solving skills were the main drivers behind their self-directed learning and commitment. They could develop a sense of purpose while finding the resolutions for the designed PBL assessment which otherwise might not be easily achievable in conventional classroom settings. The PBL assessment stimulated their thoughts and eagerness to explore relevant knowledge in the field of interest through which they could connect ideas and create meaningful solutions. Another notable aspect of the PBL assessment was students’ appreciation of the facilitation and inspiration offered by the course instructor. Students were highly encouraged by the instructor’s explanatory, flexible, and realistic teaching approaches, which could be fruitful for students’ learning enhancement. Such reflections highlighted the essential role of the course instructor in the successful facilitation of PBL projects. The synergy between teachers, learners, and the learning environment is necessary for ensuring an effective learning through PBL approaches.

However, as expected, some students encountered challenges and difficulties in adjusting themselves to the PBL environment. They wished to have more lectures and explanation from the instructor about the key points and technical terms relevant to the assessment. Some students requested the provision of additional guidance and designated course materials for self-learning process. Relevant remarks from the involved students are also quoted as reference below.

“Enjoyable content, but sometimes may need more time on the exercises.”

“I need more exercise and explanation on technical terms.”

“The mid-term test is so difficult; it is better to have some assignments.”

“It would be useful if we can get extra materials for self-learning.”

“Although the new approach for the mid-term test of this semester is good in my point of view, I would also like to have exam-like mid-term to let me know my own learning progress”;

Despite having difficulties in adjusting to the PBL environment, the students recognized the problem-solving assignment as a creative approach for their performance evaluation. Several students requested additional time for preparation and demonstration of the PBL assessment, which was quite challenging considering the packed schedule and extensive nature of the course content. Based on the findings and lessons learned in this PBL project, future teaching and learning activities could be further improved. For instance, supplementary discussion and consultation sessions could be integrated into the course design, which might be helpful to support the diverse students’ needs in developing a better understanding and adaptation to the PBL environment that may be new and challenging to them. Students’ reflections were helpful to identify both the prospects and challenges regarding PBL, which will definitely inspire future endeavour for improving teaching and learning practices in higher education institutes.

## CONCLUSIONS

This SoTL project focused on improving teaching and learning practices in higher education institutes and applied student-centric PBL approaches (with constructive and connective learning theories) to enhance students’ learning and practical skill development, which is often difficult to achieve in conventional classroom settings. At the end of the PBL assessment, the students demonstrated a remarkable increase in confidence regarding their critical thinking and problem-solving skills, which was induced by the problem-solving tasks and interactive learning activities. The results of this study indicated that the students’ desirable learning attributes could be significantly improved through active engagement and collaboration facilitated by the excellent mentorship offered by the course instructor. The majority of the students found the PBL environment very useful for their overall learning and future career development. The teaching and learning practices could be further improved to accommodate the diverse needs of students as some of them might have difficulty adjusting to the PBL environment. The positive findings from this study encourage further integration of PBL as a pedagogic tool in higher education studies to promote students’ engagement, deep learning, and professional skill development.

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