Review on Chemical Engineering Capstone Design Teaching Model to Drive Continuous Improvement and Achieving Program Outcomes

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Abstract

Project-based Learning (PjBL) is a well-known paradigm for engineering design education, with numerous case studies published in the literature. Capstone is intended to provide students with an opportunity to demonstrate their readiness for professional practice. Consequently, this paper suggests a teaching and learning model as a new paradigm for capstone design projects in an effort to perpetually enhance engineering education, particularly in chemical engineering design courses. Rigorously assessing students' knowledge of the design process is essential for understanding how to best create learning environments to facilitate the development of such knowledge. Such assessment is also quite difficult and hence there is a lack of assessment tools capable of measuring the design process knowledge of every student. The model also intends to assess whether students can explain their tasks through PBL. Besides, it provides such a structure for aligning course learning outcomes, methods of teaching including teaching strategy and learning activity, and methods for assessing students' performance. Instead of prioritizing student outcomes and mapping them to direct metrics related to curriculum, the model is also used to highlight areas of engineering education where significant opportunities exist for improving the preparedness of our students for capstone and ultimately for professional practice. This paper also addresses an early stage of a study to seek the challenges in incorporating complex engineering problems during designing a capstone design model.

Keywords: Engineering education, Project-based learning, teaching, and learning model, Chemical engineering capstone design, complex engineering problems.

Introduction

This demanding global world needs engineers with many different skills and traits, and it is the role of engineering instructors to change the way engineering is taught. To compete in a world that is changing quickly, they must utilize their problem-solving skills to educate a new kind of engineer who can hit the ground running as soon as they graduate. As engineering education in the 21st century necessitates students to be prepared for a dynamic and complex work environment. The chemical engineering curriculum must therefore incorporate experiential learning that incorporates complexity, innovation, and knowledge application in the chemical engineering curriculum.

The development of capstone design courses is an effort to bring the practical side of engineering back to the engineering curriculum (Dutson et al., 1997). Capstone is intended to provide students with an opportunity to demonstrate their readiness for professional practice (Steiner & Kanai, 2016). A defining characteristic of an engineer is the ability to work with complexity and uncertainty while solving complex engineering problems. Industry leaders, academicians, and Accreditation Board for Engineering and Technology (ABET) standards have expressed renewed interest in teaching engineers to solve real-world and open-ended problems through design education in recent years.

When six of the outcomes use the phrase "solve complex engineering problems or activities," it shows how important it is for graduates to be able to do this. In fact, these outcomes are right in line with the engineering standards set by the Washington Accord, which all engineering accreditation signatory bodies that have signed it must also follow (Mohd-Yusof et al., 2014; Mohd-Yusof et al., 2015).

Program Outcomes (PO) or Graduates Attribute (WA) describe what students are expected to know and be able to perform or attain by the time of graduation. The transition to outcome-based education, particularly in engineering education, places emphasis on the requirement that all undergraduate engineers must be able to meet the POs as stated in the 2020 Engineering Programme Accreditation Manual (BEM,2020) as follow:

- *WA1. Engineering Knowledge* – Apply knowledge of mathematics, natural science, engineering fundamentals, and engineering specialization as

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specified in WK1 to WK4 respectively to the solution of complex engineering problems;
- *WA2. Problem Analysis* - Identify, formulate, conduct research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences (WK1 to WK4);
- *WA3. Design/Development of Solutions* - Design solutions for complex engineering problems and design systems, components, or processes to meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations (WK5);
- *WA4. Investigation* - Conduct an investigation of complex engineering problems using research-based knowledge (WK8) and research methods including the design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions;
- *WA5. Modern Tool Usage* - Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering problems with an understanding on the limitations (WK6);
- *WA6. The Engineer and Society* - Apply reasoning informed by contextual knowledge -to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions of complex engineering problems (WK7);
- *WA7. Environment and Sustainability* - Understand and evaluate the sustainability and impact of professional engineering work in the solutions of complex engineering problems in societal and environmental contexts (WK7);
- *WA8. Ethics* – Apply ethical principles and commit to the professional ethics, responsibilities and norms of engineering practice (WK7);
- *WA9. Individual and Team Work* - Function effectively as an individual and as a member or leader in diverse teams and in multidisciplinary settings;
- *WA10. Communication* - Communicate effectively on complex engineering activities with the engineering community and society at large such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions;
- *WA11. Project Management and Finance* - Demonstrate knowledge and understanding of engineering management principles and economic-decision making and apply these to one's own work, as a member and leader in a team, to manage projects in multidisciplinary environments.
- *WA12. Life Long Learning* -Recognize the need and have the preparation and ability to engage in independent and life-long learning within the broadest context of technological change.

Problem-based learning (PBL) is an educational strategy in which the problem serves as the learning process's beginning point. It is essential that the problem serve as the learning process's foundation. There is an argument that project work or project-based learning (PjBL) is by definition problem-based (Helle et al., 2006). PjBL is primarily motivated by the need to adapt to a changing world. The argument is that students should strive in an environment centered on learning instead of on teaching. PjBL aims to create a student-centered environment in which assignments are attempted and completed. The more the task reflects reality, the more the students feel motivated. Therefore, working on a project can be seen as a way of organizing various simultaneous and integrated learning processes. Through PjBL, especially in capstone design, engineering students should be able to come up with creative solutions to hard engineering problems that meet the specified needs. This is demonstrated in Figure 1, where it was discovered that Graduates Attributes, (WA3) requires engineering students to be able to provide design solutions for challenging engineering problems that satisfy the requirements (Alexa Ray Fernando, 2022).

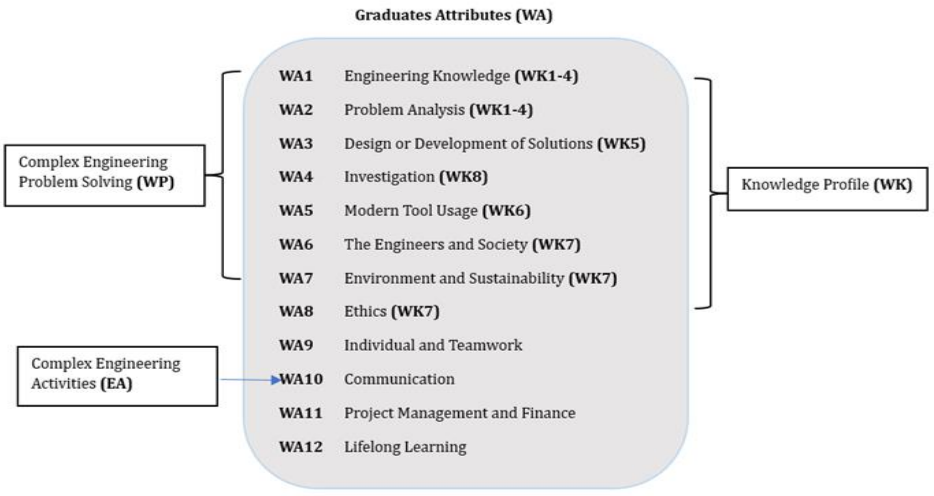

Figure 1. Complex Engineering Solving in WA's 12 Graduate Attributes

According to the IEA (2015), the range of complex problem solving is defined in Table 1.

Table 1. Definition of Complex Engineering Solving (WP)

No. & Attribute	**Complex problems** have characteristic WP1 and some or all of WP2 to WP7:
WP1 Depth of Knowledge Required	Cannot be resolved without in-depth engineering knowledge at the level of one or more of WK3,WK4,WK5,WK6 or WK8 which allows a fundamental-based, first principles analytical approach.
WP2 Range of conflicting requirements	Involve wide-range or conflicting technical, engineering and other issues.
WP3 Depth of analysis required	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.
WP4 Familiarity of issues	Involve infrequently encountered issues.
WP5 Extend of applicable codes	Are outside problems encompassed by standards and codes of practice for professional engineering.
WP6 Extend of stakeholder involvement and level of conflicting requirements	Involve diverse groups of stakeholders with widely varying needs.
WP7 Interdependence	Are high level problems including many component parts or sub-problems

It is important to note that incorporating complex engineering problems, as described by IEA, to an engineering curriculum needs at least the first attribute and any of the attributes from WP2 to WP7.

The range of complex engineering activities (EA) is defined in Table 2.

Table 2. Definition of Complex Engineering Activities

No. & Attribute	**Complex activities** mean (engineering) activities or projects that have some or all of the following characteristic:
EA1 Range of resources	Involve the use of diverse resources (and for this purpose resources includes people, money, equipment, materials, information and technologies).
EA2 Level of interactions	Require resolution of significant problems arising from interactions between wide ranging or conflicting technical, engineering or other issues.
EA3 Innovation	Involve creative use of engineering principles and research-based knowledge in novel.
EA4 Consequences to society and the environment	Have significant consequences in a range of contexts, characterised by difficulty of prediction and mitigation.
EA5 Familiarity	Can extend beyond previous experiences by applying principles-based approaches.

A programme that builds this type of knowledge and develops the attributes listed below is typically achieved in 4 to 5 years of study, depending on the level of students at entry. The curriculum shall encompass the knowledge profile as summarised in Table 3.

Table 3. Definition of Knowledge Profile

No.	**Knowledge Profile**
	A systematic, theory-based understanding of the natural sciences applicable to the discipline.
WK2	Conceptually-based mathematics, numerical analysis, statistics and formal aspects of computer and information science to support analysis and modelling applicable to the discipline.
WK3	A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline.
WK4	Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.
WK5	Knowledge that supports engineering design in a practice area.
WK6	Knowledge of engineering practice (technology) in the practice areas in the engineering discipline.

WK7	Comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; the impacts of engineering activity: economic, social, cultural, environmental and sustainability.
WK8	Engagement with selected knowledge in the research literature of the discipline.

Through capstone design projects, these attributes are extensively implemented to culminate the design experience of engineering students. Each institution of higher education has its own approach to designing and delivering capstone design projects, with the awareness that problem definition is a crucial phase of the design process that students must be properly educated and guided on.

Issues and Challenges

Additionally, according to a report on the future of engineering education in Malaysia (MOHE, 2006), employers believe that engineering graduates have the lowest level of proficiency in problem identification, formulation, and resolution and the highest level in theoretical engineering. This may indicate that students are able to fully comprehend theories but struggle to implement them practically, particularly when attempting to solve complex engineering problems through capstone design project. Kamaruzaman et al. (2018) reviewed that there are several issues and challenges to incorporate complex engineering problems during capstone design projects. Among those topics discussed are project irrelevance, faculty involvement, industrial involvement and conflict in assessment. On the other hand, research shows that learning by solving real-world problems can give context, leading to deep and meaningful learning and helping students to remember, transfer, or use their knowledge in other situations (Kamaruzaman et al., 2018). This research is necessary and should therefore be emphasized by engineering educators. Consequently, the model is used to emphasize the areas of engineering education where substantial opportunities exist for enhancing students' readiness for capstone projects and ultimately for professional practice.

In addition, varying interpretations or expectations from universities and industries make it more challenging to include complex engineering problems in capstone design projects. However, there are methods to accommodate both industry and universities in this circumstance. The first objective is to ensure that the industry understands the faculty's expectations and learning outcomes. For instance, this can be accomplished by providing vital information regarding the faculty-established learning outcomes. According to Phang et al. (2016), analysis of complex engineering challenges created by professors of engineering and reviewed by specialists, 58.5% of the issues were not deemed complex based on the characteristics listed in (ABET, 2009). Due to this circumstance, students have fewer opportunities to interact with difficult technical issues that real-world engineers encounter on a daily basis. Most projects assigned to undergraduate students are basic, unchallenging, limited, lack of real issues, well-structured, and incongruous with real-world work environments (Mohd-Yusof et al., 2014; Jamaludin et al., 2012). As a result, there is a mismatch between the needs of industry and students and what engineering education provides (Jonassen et al., 2006; J Heywood, 2005)

Mohd Yusof et al. (2014) and Phang et al. (2018) said that problems in the workplace are not the same as the problems that are often given to students in the classroom. Usually, projects at work are hard and have problems that aren't well-structured. On the other hand, projects in the school have problems that are well-structured. This can develop negative perception among students and make it hard for themselves to work in the real world once they realise how different what they learned in the classroom is from what they are experiencing. Cho and Jonassen (2002) agreed that being able to solve common classroom problems does not mean that a student will be able to solve real job problems.

To challenge students' critical thinking skills in capstone design, instructors in the industry should allow sufficient time for students to devise alternate solutions for their projects. Literature demonstrates that industrial participation in culminating design projects is always advantageous and valuable (Rasul et al., 2015; Uziak, 2016). Capstone design projects would benefit from collaboration with industry because their insights can aid in project development. The designed assignments should resemble those that students are likely to encounter in their professional careers. The stakeholders (students, faculty, all academic administrators, and the industry) must understand and identify the attributes and characteristics of complex engineering problems to incorporate them into the engineering curriculum via capstone design projects. In addition, the faculty should prepare and train engineering graduates to be capable of completing a capstone design project while taking into account other aspects of life. As an industry, engineering professional organizations, and accreditation bodies place a greater emphasis on the solution of complex engineering problems, and students need to be able to identify and define complex engineering problems. As a result, the purpose of this research is to develop a teaching and learning model for the capstone class among final-year students and hope that is simple enough for students to comprehend. Developing appropriate and effective teaching methods, techniques, and strategies is essential for a successful teaching process.

Learning Theory applied in capstone project

McHenry et al. (2005) introduced constructivism as a learning theory that facilitates the growth of engineers' competencies for engineering practice and through graduate education. As far as engineering education at the undergraduate level is concerned, the teaching and learning approach focuses on the development of specific actual knowledge that, when intellectually combined, enables the understanding of engineering principles, scientific laws, and mathematics applications required to conceptualize and execute design-oriented solutions to problems.

The cognitive learning theory of cognitivism supports this approach. As long as engineers apply their knowledge to real-world situations, an engineering education based on cognitive processes is sufficient for preparing engineering graduates. Therefore, educators must implement this theoretical constructivist learning approach because it will be able to challenge or encourage students' metacognitive and cognitive thinking skills in the context of solving complex engineering problems via capstone design projects. Moreover, through this method, students will reflect on their own experiences to construct their worldview. This implies that they will develop their own norms and mental models to comprehend their own experiences.

Figure 2 is an example of a constructivist illustration of such a process model through constructivism.

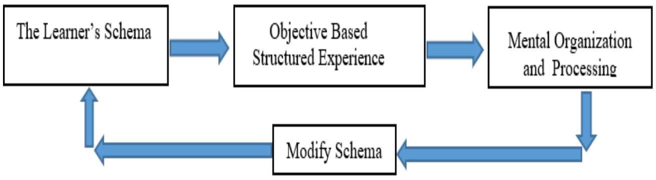

Figure 2. The process model of constructivism

This process model demonstrates that constructivism encourages the mental construction of the student's reality (experiences) and that the student generates new understanding through the mental processing of each new experience about existing knowledge. In addition, constructivism influences the learning process through curriculum, instruction, and assessment, but this will not be elaborated upon in this paper. To manage and evaluate capstone design assignments, a model is utilized.

Literature Review

New labor market demands driven by industry 4.0 advancements necessitate a transformation in engineering education. According to M. Krsmanovic (2019), UNESCO's concern is to train engineers to satisfy the labor market demands of modern labor. This demonstrates that STEM occupations have increased dramatically in recent years. This study is being undertaken concerning the existing situation and future developments to develop engineers who can address the great problems of the moment in real life. In an age of growing globalization, engineering education must emphasize transferable abilities and allow STEM graduates to develop cross-capacity, making them more marketable and flexible in their working environment. Furthermore, because tertiary education as a public good foster a high level of trust among graduates and businesses, there is a need to introduce a more holistic approach to engineering education, with the possibility of reorganizing current practices in the curriculum to better prepare engineers for future challenges.

In addition, in capstone design, it is essential to equip future engineers with these skill sets to meet the industry's current demand. Interactive methods are needed to be introduced to chemical engineering students as most elements of Industry 4.0 such as augmented reality (AR) and virtual reality (VR) and internet things become important nowadays (Oveissi & Ghadi, 2021). The successful implementation of this initiative has prompted us to investigate the possibility of converting some of our traditional teaching techniques to 4.0 versions as prospective hands-on activities. According to Chandrasekaran et al. (2013**)**, they stated that improving students' knowledge and facilitating their transition into the workforce requires effective collaboration between educational institutions and industry partners. Globally, project-based learning (PBL) is well-developed and implemented in the majority of engineering institutions and departments. Universities are thought to be the location where new information is identified, and industry is thought to be the setting where knowledge is put into practice.

Practicing design is one of the fundamental processes in engineering and all other related engineering activities. In one way or another, accreditation bodies such as the Accreditation Board for Engineering and Technology (ABET), Engineers Australia (EA), and the European Accreditation of Engineering Programmes (EUR-ACE) stipulate that the ability to identify, formulate, and solve engineering problems are essential skills in an engineering program. Steiner & Kanai (2016**)** has proposed a new progress model for capstone, which highlights its unique role in the engineering education curriculum for continuous improvement. The basic assumption is students should be prepared and able to work on an open-ended real-world project and show that they can use the knowledge and abilities they've acquired so far to address a problem in the real world.

Campbell et al. (2015) have defined a generation as a group of people born around the same time who grow up in the same cultural environment and then shape that culture. Generation Z students are viewed as risk-averse and distinct, and universities must be prepared to meet the challenge of educating this new generation (Moore et al., 2017). As a result, educators of engineering are challenged to adjust to these changes.

Capstone Teaching and Learning Model

The addition of capstone into the curriculum by ABET 2000 forced many engineering programs across the nation to address the need for providing a new form of experiential learning for students (Steiner & Kanai, 2016). Instead of focusing on the knowledge of abstract principles, analysis, and engineering fundamentals, the introduction of the capstone course meant that educators also needed to address synthesis and consider the skills needed for engineering graduates to actually use their newfound knowledge in practice (Froyd et al., 2012). To obtain outcomes, the teaching and learning environment which is applied in this capstone design model is an interactive process that requires the participation of both teachers and students. Constructionist theory (Case & Light, 2011) and collaborative learning (Mills J.E., and Treagust, 2003) are the foundations of active learning. Moreover, McHenry et al. (2005b) stated that constructivism is the most effective learning theory and process for the development of professional competence. This theory's central premise is that knowledge is not transmitted from teacher to pupil, but rather actively constructed. This is crucial in the context of engineering knowledge based on theoretical foundations (Taajamaa & Holvitie, 2018). This supports by Freeman et al. (2014), he stated that active learning and problem-based learning have been demonstrated to increase performance in STEM classes and develop the ability to solve complex problems. This is crucial for the development of successful engineers through capstone design projects.

Gomez-del Rio & Rodrigue (2022) assert that constructivist learning theory, which holds that learning is centered on understanding and creating meaning, provides the basis for the project-based learning paradigm. Nevertheless, capstone design project should be embedded with the elements of complex engineering problems to make the project more similar to the industrial world. Todd and Magleby (2005) stated that students become more interested to participate and learn well if the given projects are relevant and can help them to be successful engineers later. Modification and simplification of real-world projects would be beneficial for capstone design projects. Jin et al. (2015) made an instrument to test and improve design skills. He said that identifying and defining problems, which are the stages of design problems, are the most important design skills. In this phase, students are expected to possess the knowledge and abilities necessary to solve complex engineering problems. Therefore, students undertaking a capstone design assignment must first identify and define their engineering complex. As a result, to address this challenge, educational innovators have created a model with learning techniques such as inquiry learning, collaborative learning, flipped classrooms, project-oriented problem-based learning, team teaching, and digital environments for education (Hutchings & Quinney, 2015). The majority of these approaches are student-centered, with lecturers facilitating student interaction with information and peers. Due to the requirement to solve complex and multiparametric difficulties, the rapidly changing employment market is now calling for engineering graduates with a more comprehensive set of abilities (Ballesteros et al., 2021).

Up to this point in time, the majority of our efforts as instructors have gone into building a strong capstone course. There hasn't been a lot of effort made into exploring and using the intelligence gained from capstone projects as a way to close the knowledge and skill gap between what students need to be successful and what they really have (Steiner & Kanai, 2016). Our experience indicates that it may be possible to use capstone to assess the preparedness of graduating engineering students for professional practice and in turn use this as feedback to the curriculum to affect change. The earlier progressive model proposed for capstone in the engineering curriculum showed that capstone in the new model serves as the ‘final exam’ for all POs which is mapped to direct measures from assignment in the capstone course. Figure 3 is a model for Capstone in Relation to the Engineering Curriculum.

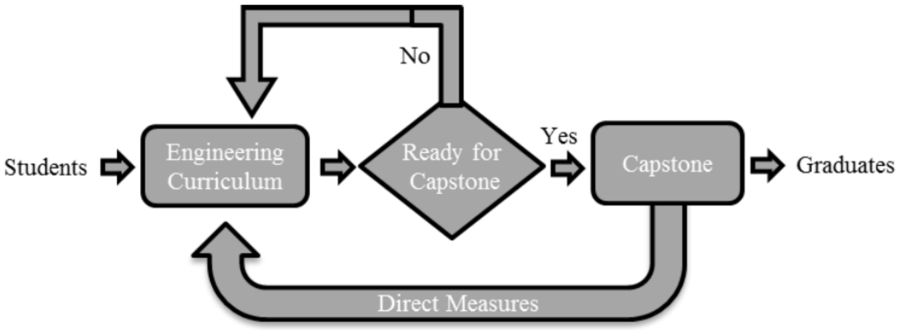

Figure 3. A model for Capstone in Relation to the Engineering Curriculum (Steiner & Kanai, 2016).

This model mapping direct measures of student outcomes to knowledge and skills. In general, engineering programmes should not rely exclusively on capstone for all direct measures of student outcomes. Rather, direct and indirect measures should be monitored from a variety of perspectives, including coursework (direct measures) and post-graduate surveys (indirect measures). This model demonstrates that it is possible to monitor all ABET student outcomes (PO) at the capstone level. The model presented shows that it possible to monitor student progress throughout the curriculum in order to ensure that students are indeed prepared for the capstone project and are consequently better prepared for professional practice.

On the other hand, the concept of the Project-based learning (PjBL) model that was proposed by Qattawi et al. (2021) covers more ground than previous models. The learning model that is utilized by senior-level engineering students participating in design-based learning may be seen in Figure 4.

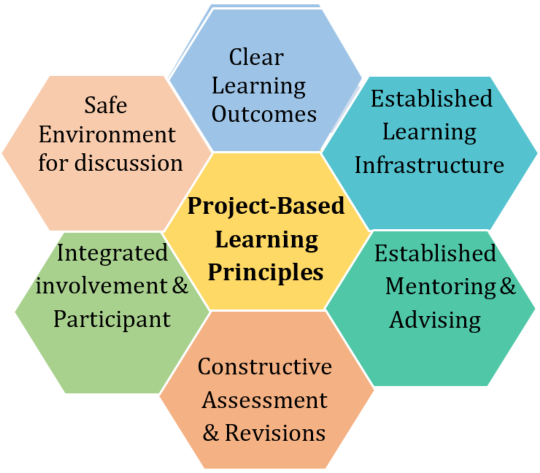

Figure 4. Project-based Learning model (Qattawi et al., 2021)

The design principles of PjBL model which can be adapted to Design-based Learning (DBL), must convey the learning objectives and ensuring the effectiveness of the model. Darling-Hammond et al. (2015) discussed the main four principles necessary for the success of PBL: those are (1) specific learning outcomes that translate into project goals and objectives, the essential questions the project will handle, and the connections between the design activities and the learning purposes the faculties are seeking; (2) learning resource that supports both student and instructor learning; and (3) revision and assessment plans. The evaluation process can be any of the form of self, peer, student to faculty, and faculty to student assessments. But it must ensure that the learning objectives are met; (4) promoting participation and involvement through the proper social organization of the students' groups, faculty, and public community.

One of the strengths of this model is that it includes (1) a learning resource that is beneficial to the learning of both students and instructors; (2) revision and assessment plans; and (3) specific learning outcomes that translate into project goals and objectives. Other strengths of this model include the essential questions that will be addressed by the project, as well as the connections between the design activities and the learning purposes that the faculties are seeking. In addition, the students' groups and forums should function to encourage participation. The structure for the necessary roles and interaction needed for project completion should be provided. These roles may include mentoring roles of faculty, mentoring, and advising from industry professionals and even students' groups. Ayas and Zeniuk (2001) proposed two additional components for the PjBL model. They highlighted the importance of (5) leader role models. The attitude for learning and monitoring the behavior and results are set by the role models. They also emphasized on (6) the necessity of creating a psychologically safe learning environment, which promotes and encourages design creativity and offers a platform for constructive discussions and feedback.

Furthermore, Jamieson & Shaw (2020) proposed a situational model in Figure 5 which this model is compared to the capstone process design course community of practice environment, where innovation can be more narrowly defined and measured based on objective improvement in the performance of a process or a product. The embedded aspect of the learning space within a community of practice adds value to this paradigm, and the larger innovation ecosystem is situational. Engineers are introduced to the community and given a practicing environment in which to solve the problem utilizing this model method.

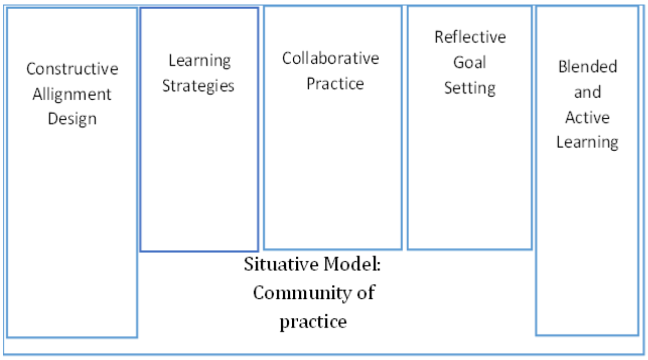

Figure 5. Experiential learning environment for capstone design supporting design, innovation, and leadership development in a community of practice (Jamieson & Shaw, 2020)

Undergraduate engineering curricula should provide ample opportunities for students to learn, practice, and demonstrate development of graduate attributes. In addition, planned opportunities for feedback on both technical and professional task performance combined with active reflection on their progress is required. This teaches students how to identify their strengths, their weaknesses, and to target their next steps to continue to learn and to develop effectively. The "ability to work as an effective team member or leader" does not develop merely by listening to a lecture on either subject! Knowledge of the principles of effective leadership does not necessarily make one an effective leader. Equally applicable to becoming an effective innovator or designer. Changing only the assessment method to one that requires performance demonstration without offering the chance to develop a skill through feedback is similarly ineffective.

The embedded nature of the learning space within a community of practice and the larger innovation ecosystem is situative (Ito et al., 2014; Jamieson, 2016) in nature and Situativity Theory (Greeno et al., 2013) is the framework and context for this study and capstone course design. The construction of learning by students in an environment where the learning objectives of a program of study are consistent with the required assessments and outcomes are central to the theory of constructive alignment (Biggs, 2012). Through this model students are introduced to and taught about team, design, and innovation processes through learning about learning, thinking, and reflective skills**.** A blended and active learning environment engages students in processes and encourages reflection and sense making (Jamieson, 2016). A community of practice provides students with mentors and models of the innovation process, as well as an environment for the development of engineering design, innovation, and leadership skills. Working in teams on goal-oriented tasks earlier and more frequently in their programme of study was also cited as potentially advantageous for developing skills necessary for the capstone design course. These student suggestions reflect a desire for earlier learning experiences that would help them develop engineering practice-related skills in addition to engineering knowledge. The intended learning outcome of the described pedagogical intervention was to provide students with opportunities to practise leadership, creativity, and innovation as contributors to open-ended capstone design projects. In conclusion, this model has a positive impact on both instructors and pupils.

Discussion

Capstone design is used by many engineering programs throughout the world to help students get ready for real-world engineering work. This literature study highlighted the significance of chemical engineering students' preparation for the capstone design course. The proposal of a suitable model for usage as a learning and teaching approach among senior project students is intriguing from a pedagogical perspective. At this point, an integrated approach has emerged by combining all elements in the past capstone design model. This perhaps the effective teaching and learning model through the PjBL strategy can be prepared for the future engineers. Besides, the direct measurement process consists of a set of instruments and actions. This instrument used to monitor student’s performance. The design and development of the model is carried out by experienced instructors who have participated in capstone design. A section could be added in the instruments for reflection. Compilation of the results from all experts in the course will provide invaluable insights for continuous improvement. The feedback may include a combination of qualitative and quantitative feedback from students and instructors. Students reflective have an important role in monitoring what individual students have learned from the course and its applicability to professional practice.

The outcomes of graduating students in this design course may benefit from this strategy. It is envisaged that the inclusion of design-based courses in engineering curricula will help bridge the gap between engineering graduates' abilities and the certifications or skills needed in the industry. Capstone design courses are highly considered valuable learning activities because they give students the chance to work on real-world engineering projects. Moreover, engineering programs are revising their curricula to better equip graduates for future problems, as they are aware of this necessity. This culminating experience allows professors to gauge the efficacy of their students' undergraduate education as a whole and to identify problem areas for remediation. This may point to a place of growth in a certain capstone design course.

Summary, Limitation, and Future Work

In conclusion, this article has gone over the crucial aspects that students need to grasp to better their performance in the capstone course that they take during their last year of study for their engineering degree. Nevertheless, project-based learning that includes a design component is very difficult and has the potential to give students quick feedback to continue to improve their performance. It is expected of engineers to find solutions to difficult technical challenges, as this is a need from the industry as well as a requirement from professional organizations and accrediting agencies. As a result, educational establishments of a higher level need to take part in this initiative to raise the number of engineers capable of resolving difficult issues in Malaysia. Education in design should be given sufficient emphasis within the engineering curriculum to reflect the fact that complex problems are most likely to be solved via the process of design. Therefore, students should work on improving their capstone design project to become better engineers for future difficulties. The major culminating design experience requires students to have knowledge and expertise to succeed. They will become more marketable to potential employers and flexible in the environments in which they operate as a result of this. It has been suggested that the fundamental ideas taught in engineering classes should be rethought to incorporate a more holistic perspective, particularly in the capstone design class. This would make engineering education more relevant to the setting of Industry 4.0.

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