PROMOTING CURRICULUM AGILITY THROUGH PROJECT-BASED LEARNING: CASE OF THE AUSTRALIAN UNIVERSITY (KUWAIT)

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ABSTRACT

Curriculum agility has recently drawn the attention of the engineering education sector as it addresses the challenging dynamic nature of engineering markets. Project-based learning (PBL) is foreseen as a successful pedagogy that adds flexibility to engineering curricula and equips graduates with long-life learning skills. The level of flexibility that PBL adds depends on many factors and one of them is the way it is practiced. In this paper, the flexibility added by the currently applied PBL model at the College of Engineering at the Australian University in Kuwait as well as a newly proposed PBL model is assessed from the perspective of experienced PBL facilitators through quantitative and qualitative survey methods. After introducing the two models and the expected enhancements added by the new model on the implementation of CDIO standards, the survey results are presented and thoroughly discussed. The results show that the new PBL model is expected to enhance the flexibility of engineering curricula but also bring to the fore the resilience to change of PBL facilitators and consequently the importance of explanatory and discussion workshops before and during the implementation of new PBL model.

KEYWORDS

Project-Based Learning, PBL, Engineering, Curriculum, Curricula, Flexibility, Agility, CDIO Standards: 1, 2, 3, 7, 8, 9, 10.

INTRODUCTION

With the increased demand for modern life and new technologies from one side and the increasingly dynamic market from the other side, the role of engineering higher education institutions is no longer graduating traditional engineers but instead, educating long-life learners who are capable of coping and quickly adapting to this very agile market while maintaining high quality standards. In addition, the rapid emergence of novel computer aided design, engineering, and manufacturing tools as well as the tremendous shift towards the internet of things and artificial intelligence also re-shape the skills and graduate attributes of tomorrow's engineers.

As curriculum agility is foreseen to address these challenges, higher education institutions are nowadays adopting new pedagogical strategies to add various degrees of freedoms to their curricula, enabling them to embed implicitly or explicitly new skills, concepts, technologies, and tools to their educational framework whenever needed by the market. For some institutions these degrees of freedom are restricted to distance or blended learning where students' diversity is the main motive for providing equal study opportunities and enabling flexibility in the "when" and "where" of learning. On the other hand, others introduce flexibility as reinventing delivery through adopting novel learning approaches focusing on the "what" and "how" of learning such as CDIO (Crawley, Hosoi, & Mitra, 2018) and Project Based Learning (Graaff & Kolmos, 2003).

In alignment with promoting curriculum agility, the College of Engineering at the Australian University in Kuwait is aiming at introducing an enhanced version of the currently implemented Project Based Learning (PBL) model with more flexibility degree of freedoms in the "what" and "how" of learning. The new model consists of PBL courses with agile learning outcomes which are expected to further nurture the student-centered long-life learning approach while enabling students to be exposed to the most recent technologies in the market.

In this paper, this new PBL approach and its alignment with CDIO standards is presented, discussed, and compared to the currently implemented course based PBL approach at the College of Engineering at the Australian University in Kuwait. The results of quantitative and qualitative surveys of PBL experienced facilitators at the Australian University are also presented and conclusions are drawn about the flexibility of both PBL models as well as the challenges that may face the newly introduced PBL approach.

PBL AT THE AUSTRALIAN UNIVERSITY AT A GLANCE

Current PBL Model

PBL is implemented at the College of Engineering at the Australian University since 2015. At that time, and to smoothly integrate PBL within the delivered programs, a course based PBL delivery was considered. Courses which best fit the PBL approach were selected from the existing engineering programs (civil, mechanical, electrical and petroleum engineering), and their delivery mode was changed from traditional lecturing to project-based learning without compromising the structure of the curricula nor the delivery mode of the remaining courses. As such, courses that require hands-on practice were mainly considered, such as programming and design courses. In total, in each engineering program, five courses were changed to PBL, one per semester, distributed over the fourth till the eighth semester of study in addition to one summative graduation project PBL experience during the last year of the program. Since then, the PBL model at the Australian University kept evolving with a lot of attention given to the assessment & feedback strategies that best serve the student-centered approach of delivery from one side as well as the students' expectations of their learning from the other side (Farhat, Nahas, & Salti, 2020), (Hussain, & Jaeger, 2018). The PBL model was also revised to consider all the requirements of the CDIO framework and in 2018, the Australian University became a member of the CDIO community, yet the course based PBL delivery concept remained unchanged.

New PBL Model

Salti, Farhat, Abdel Niby, & Zabalawi (2021) presented a new 2+2 engineering technology program that is expected to be more flexible in the "what" and "how" students learn and hence, can adapt quickly to the exponential technological growth and the corresponding required knowledge and skills. The new program is also supposed to enhance the students' graduate attributes to easily cope with the increasingly dynamic market needs and to further nurture the student-centered long-life learning skills. As far as the PBL approach is concerned, the authors argued that the course based PBL sets limited boundaries to the project as it must cover the course-specific technical course's learning outcomes which reduces the possibility of introducing multidisciplinary PBL projects that are more likely to occur in real-life engineering workplaces. As such, in the newly suggested program, they adopted a more flexible PBL approach that is inspired from the model presented by Edström, K., and Kolmos, A. (2012).

The new model incorporates 3 PBL courses only, one per semester, in addition to the summative senior graduation PBL project which endures for one full academic year. Like the old PBL approach, the PBL journey of students starts in their fourth semester of study till graduation. However, unlike the previous model, in the new PBL model, the students are exposed to one PBL course per semester only to reduce the study load that is usually heavier than traditional courses due to the PBL self-learning component. In addition, the PBL courses are no longer course specific, but have general learning outcomes that allow the facilitators to create multi-disciplinary projects extracted from realistic life scenarios and consequently, allow students to apply their pre-acquired knowledge and skills as well as elements of the courses they are taking simultaneously with the project. This enables them to conceive, design, implement and operate their projects as per their passion and learning interests and accordingly, improve their motivation, creativity, and productivity.

New PBL Model & CDIO

Compared to the old PBL model, the new PBL model is supposed to improve the implementation of standards 1, 2, 3, 7 and 8 in engineering programs at the Australian University.

As for Standard 1: the context, the flexible learning outcomes of PBL courses allow facilitators to use realistic projects which are extracted from daily life engineering problems. Any new requirements in the development of product, process, system, and service lifecycle can be reflected in PBL projects in a smoother way. Typical examples are the sustainable, human-centric and resilience characteristics of industry 5.0.

Moving on to Standard 2: Learning Outcomes, and as per its corresponding self-assessment rubric in the CDIO syllabus, the highest score is achieved when “Internal and external groups regularly review and revise program learning outcomes and/or program goals based on changes in stakeholder needs” within the institution. The flexibility added by the new PBL approach allows an implicit and relatively prompt incorporation of new stakeholder needs (e.g., in the form of project requirements at the course level). If needed and if the implicit tests led to a success, the changes may be explicitly reflected on a larger scale, i.e., on the program learning outcomes as per the regular program revision cycle.

Moreover, regarding Standards 3 & 7: Integrated Curriculum and Learning Experience, the new PBL approach enables facilitators to use multidisciplinary projects to trigger the learning experience of students. This enriches the integration between the various technical disciplinary-related knowledge and skills as well as the development of interpersonal and intrapersonal skills within a learning work environment that is better emulating real life engineering workplaces.

Finally, although PBL by itself fundamentally serves the requirements of CDIO Standard 8: Active Learning, the learning in the new PBL approach is triggered by a project that is more likely a multidisciplinary project extracted from real life scenarios. This is expected to improve students’ motivation as active learners and to further trigger their creativity as they would see themselves as young engineers who are conceiving, designing, implementing, and operating a solution that addresses a realistic engineering problem. This would result in creative solutions that satisfy students’ ambitions and preferences while integrating the knowledge and skills from the pre-requisite courses, the simultaneous courses that they are taking with the project as well as new knowledge they self-learn to achieve the various goals of project.

CURRENT VS NEW PBL MODEL FLEXIBILITY

Quantitative Survey

A quantitative survey was conducted on experienced PBL facilitators at the Australian University to evaluate and compare from their perspective, the curriculum flexibility offered by the current PBL model, and the predicted flexibility of the newly suggested PBL model. The survey addresses the following main question: How PBL facilitators at the Australian University would perceive the curriculum flexibility added by the new PBL model compared to the currently implemented one?

It hence aims at validating the following main hypothesis: From the perspective of PBL facilitators at the Australian University, the new PBL model is expected to add more flexibility to the curriculum than the currently implemented one.

Table 1. Quantitative Survey Questions

Dimension	Part 2	Part 3
Learning Flexibility (What)	CM1: The current PBL course(s) that I am facilitating is(are) flexible in terms of "What" students are learning	NM1: I believe that the new PBL approach proposed in the new curriculum will provide more flexibility in terms of "What" students are learning.
Learning Flexibility (How)	CM2: The current PBL course(s) that I am facilitating is(are) flexible in terms of "How" students are learning.	NM2: I believe that the new PBL approach proposed in the new curriculum will provide more flexibility in terms of "How" students are learning.
Learning Outcomes Flexibility	CM3: I have flexible learning outcomes within the PBL course(s) that I currently facilitate.	NM3: I expect that the new PBL approach proposed in the new curriculum will address the flaws of the current PBL approach.
Serve Dynamic Industry	CM4: The current PBL course(s) that I facilitate has(have) outcomes that meet the dynamic nature of industry	NM4: Flexible learning outcomes incorporated in the new curriculum can serve the dynamic market needs.
Interdisciplinary Interactions	CM5: The current PBL course(s) that I facilitate promote(s) interdisciplinary interactions.	NM5: The new PBL approach proposed in the new curriculum will promote interdisciplinary interactions.
Overall Flexibility	CM6: Overall, the PBL course(s) that I facilitate add(s) flexibility to the program of study.	NM6: Overall, I expect that the new PBL approach proposed in the new curriculum will add flexibility to the program of study.

Study Methodology & Environment

The quantitative survey consisted of a three-part questionnaire supported by an explanatory video. The first part aimed at collecting demographics such as age, gender, and specialty of participants. After collecting the demographics, the participants were asked to watch a five-minute video that explains the new PBL model and presents its main differences with the current PBL model that they are practicing at the Australian University. The second and third parts consisted of 6 questions each which aim at assessing the flexibility of the current PBL model (CM1-CM6) and the new PBL model (NM1-NM6), all designed based on a Likert scale from 1 to 5 where “1” represents “Strongly Disagree”, “2” represents “Disagree”, “3” represents “Neutral”, “4” represents “Agree”, and “5” represents “Strongly Agree”. To each question is associated a flexibility dimension. Table 1 summarizes the questions and the corresponding flexibility dimensions.

A pilot study has been conducted prior to the distribution of the questionnaire to explore whether any question is not clear and to identify any areas of improvement. Three random PBL facilitators have been asked to fill in the survey and some comments have been raised and addressed. After the pilot study, an updated version of the questionnaire has been distributed to the whole population which consists of 51 PBL facilitators at the College of Engineering at the Australian University who have been facilitating PBL for at least 2 semesters. The data was collected towards the end of the Fall semester of the academic year 2022-2023 and a response rate of 58.8% has been achieved (i.e., 30 participants out of 51) with 30% of participants are from Electrical & Electronics Engineering, 30% from Mechanical Engineering, 26.7% from Petroleum Engineering, and 13.3% from Civil Engineering. Moreover, 20% of the participants are females and 80% males.

Results

Data has been analyzed using the SPSS 29.0.0.0 version. Frequency and descriptive tests were implemented to extract basic statistical values such as means, counts, and standard deviations. Figure 1 summarizes the obtained mean value for all questions classified by the evaluated flexibility dimension. The corresponding standard deviation values ranged between 0.8 and 1.3 which means that the responses were relatively consistent and that the mean value may be considered as a valid variable to extract conclusions from.

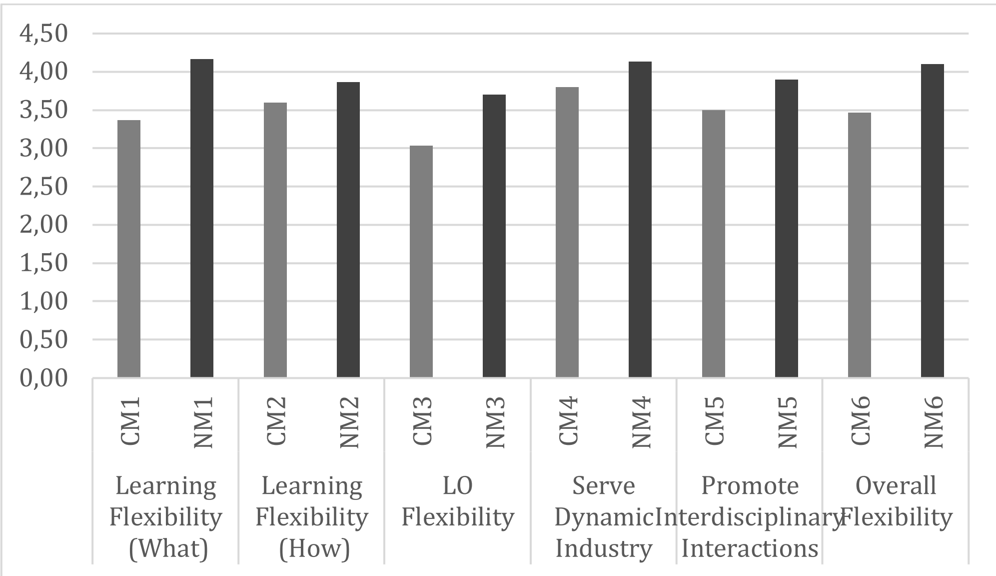

Figure 1. Quantitative Survey Results: Mean Scores

Figure 1 shows that the new PBL model scored mean values above 3.5 for all the studied flexibility dimensions which indicates that most of the AU PBL facilitators agree that the new PBL approach adds flexibility to all the studied flexibility dimensions. On the other hand, the highest mean (4.17) was obtained for “NM1: Learning Flexibility (What)” which indicates that most of PBL facilitators agree to strongly agree that the new PBL model adds more flexibility in terms of “what” students are learning. Moreover, the lowest mean (3.03) was obtained for “CM3: LO Flexibility” which indicates that PBL facilitators are not quite convinced that the current PBL courses have flexible learning outcomes. This is compatible with the stated hypothesis and the objectives of the new PBL approach (Salti, Farhat, Abdel Niby, & Zabalawi, 2021).

Moreover, to compare the new to the current PBL models in terms of flexibility from the perspective of PBL facilitators at AU, the "Normalized Flexibility Enhancement (NFE)" ratio is calculated for each of the studied six flexibility dimensions. It is calculated as the mean score of the current PBL model (CM) subtracted from the mean score of the same dimension in the new model (NM) then normalized to the highest mean difference as per equation (1) and (2).

$$FE_i = \frac{NM_i - CM_i}{max_i\{NM_i - CM_i\}}\% \quad (1)$$

Where

$$max_i\{NM_i - CM_i\} = NM_1 - CM_1 = 0.8 \quad (2)$$

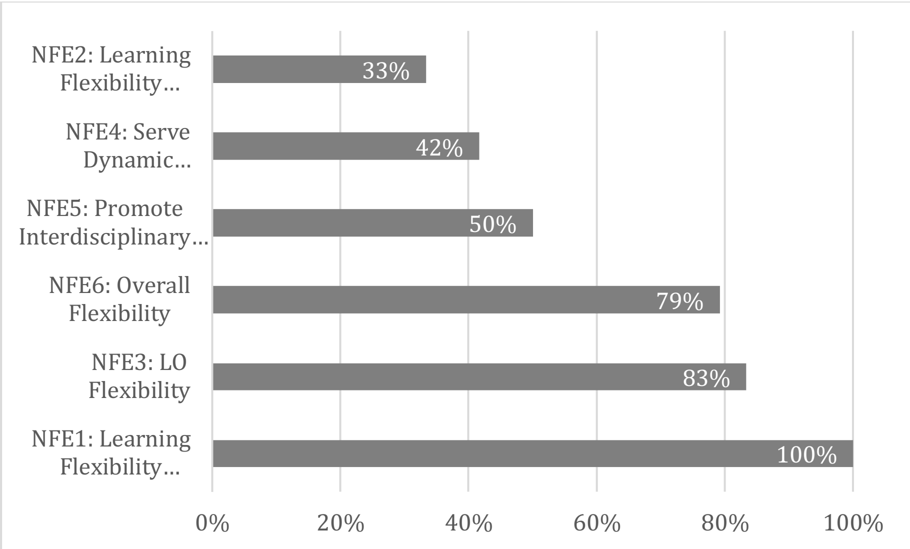

Figure 2. Quantitative Survey Results: Normalized Flexibility Enhancement Ratio

Figure 2 shows the sorted Normalized Flexibility Enhancement (NFE) ratio for all the studied flexibility dimensions. All the obtained values are positive which indicates that PBL facilitators at AU agree that the new PBL approach will enhance the flexibility at all the studied dimensions. Interestingly, the "Learning Flexibility (What)" dimension scored the highest NFE (100%) followed by the "LO Flexibility" (83%) and then "Overall Flexibility" (79%). This means that the PBL facilitators at AU are convinced that the new PBL approach will add more flexibility, when compared to the current PBL approach, to the knowledge component of the PBL courses and to their learning outcomes which will certainly reflect on the overall flexibility.

On the other hand, the lowest NFE score was obtained for the flexibility dimension related to "How" students learn which is expected since the PBL student-centered implementation approach would be almost the same in both scenarios and the PBL facilitators did not yet experience the new PBL model to consider the student motivation aspect that was discussed earlier. Surprisingly, although the new PBL approach is expected to promote interdisciplinary interactions and to better serve the dynamic nature of industry, PBL facilitators at AU are not very convinced that this would be the case if the new PBL approach is implemented. This may be linked to their unfamiliarity with the practical implementation techniques of the new PBL approach from one side and to their resilience to change from the other side.

Qualitative Survey

To unveil the pros & cons of the current vs the new PBL model from the perspective of AU PBL facilitators, a qualitative method is followed. It consists of a four-question interview that aims at discovering the flaws and strengths of both the current and the new PBL model as follows:

- What are the flaws of the current PBL approach regarding its limited flexibility?
- What are your thoughts with regards to the flexible learning outcomes offered by the new PBL approach?
- How do you think the new PBL approach will better serve the facilitator as well as the learner?
- What are the challenges that may face the implementation of the new PBL approach?

The interview questions were distributed via e-mail. Eleven PBL facilitators from the College of Engineering responded to the interview questions all through replying to the e-mail which increased the accuracy of the data collected. The NVivo12 qualitative research data analysis software has been used to analyze the interviews text and generate a frequency table. For the qualitative survey, the most experienced PBL facilitators were selected (3 to 7 years of experience).

Based on the design of the interview, the data was categorized into 4 categories: (1) Pros of current model, (2) Cons of current model, (3) Pros of new model, and (4) Cons of new model. Multi-level coding process was followed. The main core codes were selected based on the highest number of references. Only codes with at least three references were selected in the last layer of the coding process. To check whether the new model addresses the flow of the current model, the identified cons of each model were compared to the pros of the other one. Tables 2a and 2b show the cons of the current model vs. the pros of the new model and the pros of the current model vs. the cons of the new model respectively. In these tables, each line presents a code with its "reference" representing the identified keyword, its "frequency" representing the code's repetition count in the interviews text, and its "percentage" representing the code's occurrence percentage among all other identified codes.

As seen in Table 2a, the main disadvantage pointed by facilitators within the current PBL model is that it has a limitation in terms of topic versatility. On the contrary, looking at the advantages foreseen by the facilitators in the new model, many pros have been discussed. Among the most influencing factors, facilitators expect that the new model will bring its great benefit to the students with 7 references with this context. Also, positiveness is highlighted in the context of learning outcomes, experiences, and even added value which is expected to address the gap of topics limitations in the current model. The results obtained in the qualitative survey are hence coherent with the conclusion drawn from the quantitative one as facilitators seem to agree that the new model will be beneficial to the students and the PBL experience in general.

On the other hand, Table 2b shows that the main advantage of the current model from the perspective of PBL facilitators is that it has no major flaws whereas the main disadvantage of the new model is that it will be more challenging. Combining these observations with the numerous advantages of the new PBL model and the cons of the current model stated by the same facilitators is an indicator of a resilience to change. Hence, it is expected when facilitators get more familiar with the new model, this disadvantage will be overcome, and all the foreseen pros will bring its successful outcomes. This suggests that a sequence of professional development sessions and workshops are needed prior and during the implementation of the new PBL model as per CDIO standards 9 and 10 to overcome any resistance that may occur at the initial phase of implementation.

Table 2a. Frequency Table of Codes

Current Model			New Model		
Cons			Pros		
Reference	Frequency	Percentage	Reference	Frequency	Percentage
Limited Topics	3	21.43%	Benefits Students	7	19.44%
			Positive Outcomes	5	13.89%
			Positive Learning Experience	4	11.11%
			Good Project Experience	4	11.11%
			Added Value	3	8.33%

Table 2b. Frequency Table of Codes

Current Model			New Model		
Pros			Cons		
Reference	Frequency	Percentage	Reference	Frequency	Percentage
No Major Flaws	3	60%	More Challenging	3	60%

DISCUSSION & CONCLUSION

The engineering field is nowadays very dynamic due to the increased demands for modern life and new technologies that are emerging every day. This reflects on the engineering higher education sector which is required to produce engineers who are long-life learners from one side and are aware of the most recent technological trends and their development from the other side. Curriculum agility is foreseen to address the challenges. As such, higher education institutions started to introduce new teaching pedagogies and other strategies to add flexibility to their curricula. Project Based Learning (PBL) which is a relatively new teaching pedagogy is suggested as a flexibility degree of freedom in engineering curricula as learning is triggered by a real-life scenario project that is usually extracted from everyday engineering problems. However, the level of flexibility that PBL adds to an engineering curriculum depends on the way it is implemented.

This paper presented two PBL approaches, the course based PBL which is now being implemented at the College of Engineering at the Australian University in Kuwait and a new PBL model that is yet to be implemented. This was followed by illustrating the enhancements that the new PBL model is expected to add on the implementation of the CDIO standards at AU. Finally, the results of a quantitative and qualitative survey research are presented to draw conclusions on the flexibility degree added by both PBL models from the perspective of experienced PBL facilitators at AU. Whereas the quantitative survey addressed the flexibility offered by each of the two models, the pros & cons of these models were investigated using the qualitative method.

When comparing both models statistically, the main findings from the quantitative study revealed an indication that facilitators are somehow satisfied with the current model but also have better expectations from the new model. Moreover, using the “Normalized Flexibility Enhancement (NFE)” ratio, results showed that PBL facilitators at AU are convinced that the new PBL approach will add more flexibility, when compared to the current PBL approach, to the knowledge component of the PBL courses and to their learning outcomes which will certainly reflect on the overall flexibility. Moreover, the qualitative study uncovered promising results regarding what AU facilitators are expecting from the new PBL model such as bringing more benefit to students and positiveness in terms of learning outcomes and student experiences. While this optimism is forecasted by AU facilitators, they have expressed their fear that the new model may impose more challenges in its implementation which is expected to diminish once the new model gets into the implementation phase due to the learning curve theory. This suggests that the new PBL model needs to be clearly introduced to the facilitators to overcome any resistance that may occur at the initial phase of implementation.

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