Assessment of a project-based learning versus conventional engineering program using analytical hierarchy technique

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Abstract

Education is the backbone of any nation and evolving the teaching methodology is crucial to improving the quality of delivered programs. At the heart of education is engineering, the main driver of technological advancement and economic prosperity. Conventionally engineering programs were delivered as a set of courses with a capstone project to demonstrate the student's learnings. However, project-based learning (PBL) model had been recently proposed by some engineering program to widen and increase the application of the learning resulting in a market-ready graduate. This work aims to quantitatively compare the quality of education in both; conventional engineering programs and engineering programs adopting the PBL model using an evaluated set of quality indicators. The quality indicators are divided into three different primary ones, each has a set of secondary indicators. The first primary indicator is the taught curriculum, with secondary indicators being the availability of resources, compatibility with the market, and maturity of the curriculum. The second primary quality indicator is the operations within the program, with secondary indicators being the quality of the instructors, time spent between students and instructors, and the structure of the operations. The third primary indicator is the graduate, with secondary indicators being the average pay of graduates, employment ratio, and employment within the engineering sector. Using the analytical hierarchy approach (AHP), the relative importance of each quality indicators is identified based on a survey of 10 experts with teaching experience in both types of programs, however, to eliminate bias, only 4 expert's opinions were used to drive the data. Using data gathered from the surveys, a weighted value indicating the importance level of the indicator is calculated. It was found that the curriculum was the most important quality indicator, this is followed by the operations within the program, as they both signify direct input to the educational model. Following that, each primary and secondary indicator was assigned a value for each type of the engineering programs based on a survey form the 4 non-biased experts teaching in both types. This value indicates the conformity and fulfillment offered by the program with reference to the tackled indicator. Based on this value and the relative importance of the indicator calculated earlier an overall rank is calculated for each program. The results indicate that engineering programs adopting the PBL model showed a marginally higher overall rank of 0.8 compared to 0.76 for conventional programs.

Keywords: PBL model, analytical hierarchy approach (AHP), sustainable design engineering program (SDE), university of prince edward island (UPEI).

1. Introduction

Nowadays, engineering programs are facing pressure from the industry and accreditation boards to introduce graduates who are mastering technical and soft skills such as working in a team-based environment, managing different projects, communicating effectively, and others. Thus, Engineering programs strive to adopt new pedagogical models such as the project-based learning (PBL) model.

This paper aims to elaborate on the project-Based learning and provide a quantitative assessment using Analytical Hierarchy Technique for both; conventional engineering programs and new programs adopting the project-based learning model. The paper will also shed light on the sustainable design program of the University of Prince Edward Island that applies a project-based learning model in the design courses to integrate practical experience with theoretical background in the engineering curriculum in all years of undergraduate studies. Although the literature has shed light on the PBL model, it falls short in quantitatively evaluating the quality engineering programs adopting a PBL educational model and comparing it to the conventional engineering program (Hotaling *et al*. 2012) [8].

2. Project based learning

The literature has explained Project-Based Learning in engineering education as one that requires working in teams to provide a solution to a non-trivial multidisciplinary engineering problem and handing a report and an artifact such as a prototype or a digital simulation (Palmer & Hall, 2011) [13]. PBL has also been distinguished from other models of learning by requesting students to apply rather than acquire knowledge with time management, and self-direction is key to the model's success (Gavin, 2011) [7]. In the same line, Chandrasekaran *et al*. (2012) [3] claimed that in PBL, students are required to provide a solution to an open-ended problem by applying previously acquired knowledge. Al-Balushi & Al-Aamri (2014) [1] defined PBL as a type of inquiry-based learning with a context provided through authentic questions and problems within real-world practices. Moreover, to distinguish PBL from other forms of learning, such as problem-based learning or experiential learning, Kokotsaki *et al*. (2016) [11] explained that in PBL, students are usually required to construct an end product or an artifact.

Generally, in Engineering programs, the design courses are a central function of engineering practice and are the courses entitled to practicing project-based learning. However, the design experience in conventional engineering programs is being integrated into other courses or limited to the capstone design courses, which are historically defined by Brown & Seidner, 1997 [2] as employing product-based learning that involves problem-solving and project management activities to produce a prototype to an external party. Whereas in project-based learning, the design experience can range from a set of standalone courses to a point where the project-based approach is fully integrated into the program, as in the case of the Sustainable Design Engineering Program of the University of Prince Edward Island (UPEI).

Earlier in the literature, it has been claimed that in project-based learning, students accept control of what needs to be learned and how it should be learned (de Graaff & Ravesteijn, 2001) [4]. In the same vein, students are argued to be more active learners in the PBL model (Chinnowsky *et al*., 2006). And are better engaged in solving the problem as they experience a higher level of freedom and challenge compared to the conventional classroom learning mode (Wurdinger *et al*., 2007). Moreover, Kelly (2007) [10] argues that the PBL is a suitable mean to achieve competence-based education and that students get opportunities to interact with a vast network of people through projects in the PBL model; hence their skills, creativity, and innovation ability tend to develop faster.

More recently, the benefits of PBL were explained by many authors and include self-motivation of students, efficient team development, exposure to real multidisciplinary problems, development of skills and coping with ambiguity, as well as offering possibilities for developing technical and behavioral competencies (de Los Rios, 2010 and Palmer & Hall, 2011) [5, 13]. Similarly, Gavin (2011) [7] claimed that the PBL model provides an opportunity for deep and life-long learning. Additionally, Johri & Olds (2011) [9] claim that early interaction with the industry facilitates the shift from student to a professional engineer.

It was also claimed by Chandrasekaran *et al*. (2012) [3] that Project-Based Learning is perceived to shift the learning process from being teaching-centered too student-centered. And during this learning process, students gain many career-related soft skills such as networking, marketing, and public speaking. The same was confirmed by Hotaling *et al*. (2012) [8], who concluded that students involved in solving open-ended, real-world problems showed improved performance in innovation, analysis, proof of concept, and communication skills.

The benefits mentioned above make the PBL model a logical pedagogical strategy in engineering education that prepare students to fulfill the engineering graduates' attributes. However, despite those benefits, the PBL model is not free of shortcomings. For example, some authors highlighted students' dissatisfaction with the idea of not knowing 'exactly what they had to do.' Also, the availability of resources, study rooms, and expertise always poses a challenge in a PBL model (Edward, 2004 & Gavin, 2011) [6, 7]. It was also mentioned that students in a PBL model should be ready to bear greater responsibility for their learning and have the willingness to engage in a pre-professional work experience which is a bit challenging for some students who are not used to working on open-ended problems (de Los Rios, 2010) [5].

Thus, to quantitatively assess the net benefit of applying a PBL model in engineering education, the authors of this paper will analyze and compare the quality indicators of engineering programs adopting the PBL model against conventional engineering programs using the Analytical Hierarchy Technique.

3. The Sustainable Design Engineering program (SDE)

The Sustainable Design Engineering program (SDE) is a less than 1o-year-old program at UPEI, accredited by the Canadian Engineering Accreditation Board. It operates in two different Continents, the North American, and the African continents.

The program is a 4-year program that adopts a project-based learning methodology. The design courses constitute 33% of the curriculum in which students are required to work in teams to solve a real engineering problem presented by an industry partner. First-year design courses worth six credit hours are named Engineering Communication and Engineering Analysis and are presented to the students as a "community design program" where students need to work on community projects, mostly with non-profit or government organizations. Second-year design courses worth six credit hours and named Engineering Projects I and Engineering Projects II are presented to students as "junior design clinics" where students work with industry partners to solve a simple engineering problem. The third-year and fourth-year design courses; worth together twenty-four credit hours, are named, Project-Based Professional Practice I, Project-Based Professional Practice II, Project-Based Professional Practice III, and Project-Based Professional Practice IV. the third and fourth-year design courses are presented to the students as the "senior design clinics" where students are required to work as consultants to an industry partner for a fee and provide a solution to the presented engineering problem within a defined set of requirements and constraints.

The design courses aim to apply knowledge more than acquiring theory, so the program is structured so that the core design courses are complemented by theoretical courses as prerequisites or corequisites, as shown in figure 1, to help students gain the required theoretical knowledge to solve real-life engineering problems. The design courses are also served by an industry partnership group whose responsibility is to recruit community or industry partners to propose a real-life engineering problem and assess and select the most suitable projects for the students. In all the design courses, students are required to follow the engineering design process as shown in figure 2, implement project management skills, meet with the community/industry partners to discuss project scope, requirements, and constraints, and present and discuss their conceptual, preliminary, and final designs. The group meetings are usually held in an ideation room, not lecture halls, to simulate a professional working environment and allow for individualized mentoring by the instructors. For successful completion of the design courses, students are required to fulfill the community/industry partner requirement and the academic requirement set by the instructor of the design courses. At the end of the academic year, students can also present, commercialize their prototypes and defend their project designs before academics, industry partners, peers, and government officials at the design Expo event.

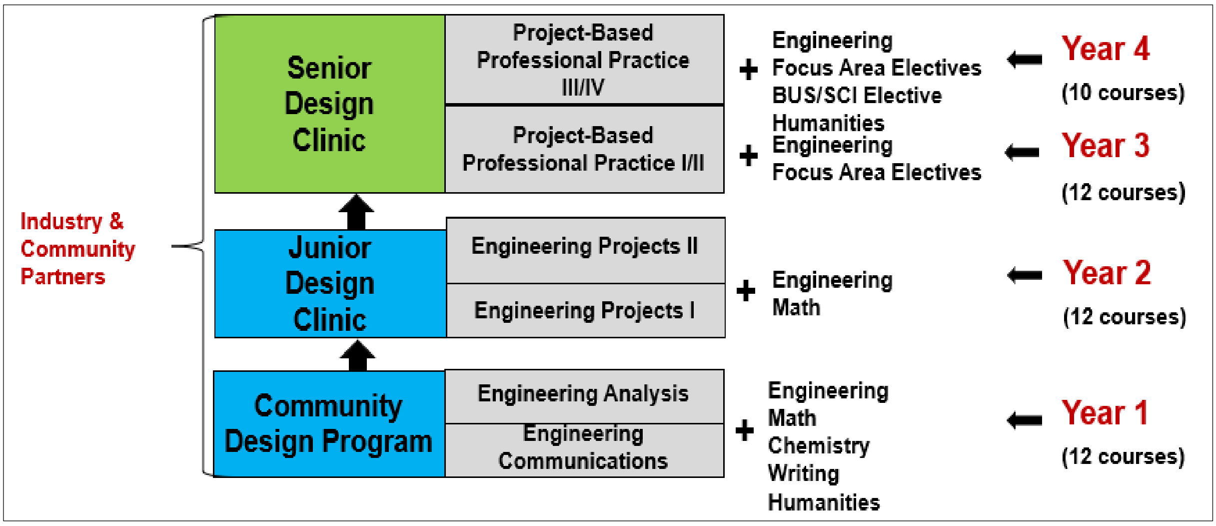

Fig 1: SDE program structure

Fig 2: Engineering design process

4. Methodology

To analyze new pedological models such as the PBL model, it must be compared against a baseline. The comparison will provide means to decide if the new approach is practical and provide an edge for the adoption program. It will also help in assessing the relative impact of the new model on the adopting program compared to traditional programs. There are two primary methodologies to evaluate data, qualitative and quantitative methods. In qualitative analysis, emphasis is made on interpreting opinions based on personal accounts illustrating conclusions. On the contrary, the quantitative analysis relies merely on numerical data. In this research, the authors adopts a hybrid technique where qualitative data and opinions are quantified to allow for measurement and reduce bias, this is called the analytical hierarchy technique.

4.1. Analytical hierarchy approach

This study will be using the analytical hierarchy process (AHP) to compare programs adopting project-based learning model against conventional engineering programs. AHP is a decision-making technique developed by Thomas Saaty (Saaty, 1990) [16]. AHP provides a framework to quantify the criteria assigned to compare different options. It combines experience indicating qualitative assessment and translates this into quantifiable numbers for clarity. Three main principles govern AHP (Saaty, 1986) [15].

- The decomposition of the problem into a set of elements, each element contains other set of sub-elements in a second level, the number of levels is not limited, each element at any level can be further divided into sub-elements forming a new lower level. Elements at different levels don't necessarily be technically or functionally dependent on the upper level; rather, it can be merely structural or proprietorial dependence.
- The second principle is the relativity of each element when compared to the other element. This can be indicated as comparative judgment. This gives rise to a matrix containing the relative importance for each element at different levels. From this matrix principle, the eigenvalue can then be obtained. An example of the generated matrix can be found below, where aij denotes the relative importance of criteria i comparing with j

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \cdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix}$$

- The third principle is the linkage of each level to the lower level. This is concerned with the synthesis of the priorities. The lower-level elements are given importance, and the overall priority or global priority is obtained by multiplying the local lower-level priority by the priority at the top level. The sum of this multiplication for all the elements in the lower level indicates the global priority of the factor.

The relative weights between different factors is assigned by numbers, as the number increases the importance of one factor over the other increase. Table 1 shows the cross-factor ratings.

Table 1: Fundamental weighing scale, reproduced from (Saaty, 1990) [16]

Intensity of Importance of an absolute scale	Definition	Explanation
1	Equal Importance	Two Activities equally contribute to the objective
3	Moderate importance over one another	Experience and judgment strongly favor one activity over the other
5	Essential or strong importance	Experience and judgment strongly favor one activity over the other
7	Very strong importance	Activity strongly favored based on practice
9	Extreme Importance	The evidence favoring one activity over the other is of the highest order of affirmation
2,4,6,8	Intermediate values between two adjacent judgments	Intermediate values when compromise is needed

AHP is designed in a way where mere number crushing is not possible, several parameters must be checked to make sure of the validity of the indicated numbers (Liang *et al*., 2017) [12].

- The maximum eigen value (λ_{max}) is obtained and compared to the number of factors in the comparison (n), the mathematical theory indicates that both values must be equal if the matrix is consistent. However, this is not possible in practice, some deviation may be there and accordingly other indicators are developed.
- Consistency ratio (CR) is calculated using equation 1 below, where CI is the consistency index and RI is the average random index. CI can be obtained using equation 2 while RI is obtained from table 2. If CR < 0.1 then the matrix is consistent and acceptable, however, if the CR > 0.1 then the matrix must be modified till it is consistent.

$$CR = \frac{CI}{RI} \quad (1)$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (2)$$

Table 2: Average Random Consistency Index (Hanwei Liang, 2017) [12]

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

4.2. Quality indicators

To properly assess a program, first the factors affecting the quality must be determined. In this work these factors are called the quality indicators. The quality indicators will be divided into three main primary quality indicators, Curriculum, Operation and Graduate. From these, secondary indicators are developed, as explained and shown in figure 3 below.

4.2.1. Curriculum

The curriculum is the core of any program; hence it is considered one of the primary quality indicators. Engineering has been taught for hundreds of years. However, continuous changes took place in the curriculum, improving it and coping with technological advancements (Tractenberg *et al*., 2020) [17]. Several secondary indicators can be considered when evaluating curriculum, and they are as follows:

- Availability of resources. The resources are then used to build the appropriate content needed to convey the intended message and build the required skills.
- Linking the curriculum to the job market. Linking the curriculum to the market ensures that graduates are qualified and ready to join the workforce immediately.
- The more time the curriculum is tested, the higher the chances of success. This makes the maturity of the curriculum an important secondary indicator to assess.

4.2.2. Operations

Another pillar of a successful program is its operations. The operations as a primary quality indicator connect all the program components and ensure it is properly coordinated and in coherence. Appropriate operations cut it short and make it easier to implement and gain the intended output of a program. When evaluating operations, the following secondary indicators need to be considered:

- The quality of the instructors in delivering the curriculum is one of the secondary indicators to be considered. This is especially important when tackling innovative and new approaches. With the increasing pace of technological advancement, the quality of the instructor is becoming significantly crucial to the success of an educational program.
- Structuring the operations or having clear guidelines that instructors follow is crucial to ensure that standard quality education is delivered, especially in programs that offer professional degrees, such as the engineering program.
- The availability of instructors to students plays a role in shaping the minds of the next generations. The longer the contact hours, the higher the probability of proper knowledge transfer.

4.2.3. Graduate

The outcome of the educational process is the graduate. The target is to graduate a highly skilled and market-oriented graduate. This reflects the success of the other two primary indicators. The following secondary indicators can track this:

- The ratio between the number of employed graduates to the total number of graduates can be considered as an indication of the readiness of the graduate to join the workforce.
- Average pay is another secondary indicator. It indicates how appealing the graduate is to employers and their tendency to attract good quality graduates.
- The number of employed graduates in the engineering field is another secondary indicator of how appealing the graduates are to the engineering sector.

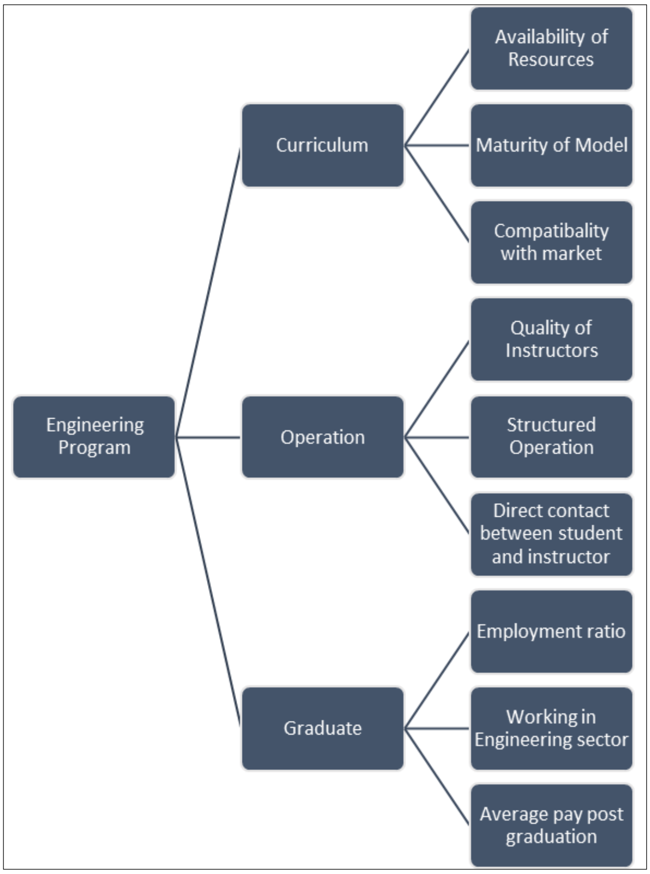

Fig 3: Engineering program indicators

5. Results and discussion

In this section the AHP process will be followed and applied in the comparison of PBL model represented in the SDE program and conventional program engineering program.

After identifying all the primary and secondary quality indicators, each indicator must be assigned a certain weight for the AHP process. In this process the first step is to weight each level individually. The process of weighing different factors goes in the following sequence:

- Calculating the weighted value that reflects the importance of each quality indicator at both the primary and secondary level.
- Assigning a value for each quality indicators at both the primary and secondary level in each type of engineering program.
- Calculating an overall rank for each type of engineering program by multiplying the weighted value of each secondary quality indicator by the assigned value for it, the sum of the calculated ranks is obtained and multiplied by the weighted value for the primary indicator corresponding to them.

To eliminate bias ten different experts with more than twenty years of experience in both program schemes were asked to weight each indicator against each other. As per the acceptance criteria of CR<0.1 to eliminate bias, only four of these opinions were considered. The experts opinions were then averaged.

5.1. Calculating the weighted value of each quality indicator

At this stage the different indicators are weighted against each other. The more important the indicator is the higher the number, the scale is discussed earlier in table 1. The average number obtained from the results of the four different non-biased assessors. CR is assessed using the eigen, subsequently a normalized table must be generated from the results. CR calculations are done to make sure that the matrix is consistent. The consistency of the matrix means that the assessment is not merely crunching numbers, and that the assessment is valid. As CR reach 1 corresponding to 100% this means the numbers are very inconsistent, for this study the maximum inconsistency accepted is 10% or a CR of 0.1.

5.1.1. Level 1 (primary quality indicators)

At this level the primary quality indicators are assessed. The primary indicators are the curriculum, program operations and graduate. Each indicator is compared against another, the average obtained from the four non-biased assessors is evaluated to two decimal places and elaborated in table 3. Table 4 also shows the normalized value, this is done to obtain the weights of each factor. The normalized table is also used to check for the adequacy of the matrix using eigenvalues and hence obtaining the CI and CR.

Table 3: Evaluation of level 1 factors

	Curriculum	Operation	Graduate
Curriculum	1.00	1.60	2.67
Operation	0.63	1.00	2.20
Graduate	0.38	0.45	1.00
SUM	2.00	3.05	5.87

Table 4: Normalized table for level 1

	Curriculum	Operation	Graduate	Weight
Curriculum	0.500	0.524	0.455	0.439
Operation	0.313	0.327	0.375	0.338
Graduate	0.188	0.149	0.170	0.169
SUM	1.00	1.00	1.00	

From table 4, it can be concluded that on average curriculum and operation had a moderate superior importance over the graduate, with curriculum marginally higher in importance. This is also shown in normalized values table. The weight of each factor is obtained by taking the average of the row it is in. The matrix adequacy check results are presented in table 5. It is clear that the CL and CR are within the acceptable range concluding that this analysis is adequate.

Table 5: Matrix adequacy parameters for level 1 evaluation

Parameter	Value
CL	0.005
CR	0.009

5.1.2. Level 2 (secondary quality indicators)

Similar to the analysis done in level 1, on the second level the secondary indicators are tested against each other using the input of the experts and the average is taken. The tested secondary indicators from the second level must fall under the same first level primary quality indicators so that they can be assessed against each other. Accordingly, three different second level analysis are done for each first level indicator.

5.1.2.1. Secondary indicators of the curriculum

Under curriculum there are three different secondary indicators, namely; the availability of resources, link with the market and maturity of the curriculum. Table 6 shows the average results of importance. It is clear that the availability of resources is the most important indicator compared to the two other secondary indicators. This is followed by maturity of the curriculum and then with close proximity the link with the market. The normalized table 7 also confirms these conclusions. Table 8 showed that the CL and CR value are withing the acceptable range.

Table 6: Level 2-curriculum evaluation

	Resource	Maturity	Market
Resource	1.00	2.067	2.00
Maturity	0.484	1.00	1.267
Market	0.500	0.789	1.00
SUM	1.984	3.856	4.267

Table 7: Normalized table for level 2 curriculum evaluation

	Resource	Maturity	Market	Weight
Resource	0.504	0.536	0.469	0.503
Maturity	0.244	0.259	0.297	0.267
Market	0.252	0.205	0.234	0.230
SUM	1.00	1.00	1.00	

Table 8: Matrix adequacy parameters for level 2 - curriculum evaluation

Parameter	Value
CL	0.005
CR	0.009

5.1.2.2. Secondary indicators of the operations

Under operations as a primary quality indicator, there are three secondary indicators: the quality of the instructor, the structuring of the program, and the contact hours between instructor and students. It can be concluded that the quality of the instructor is the dominant indicator, significantly superseding the structure of the program and the contact hours. How structured the program is found to be the second most important secondary indicator with only a marginal difference when compared to the number of contact hours between student and instructor. This can be seen in both tables 9 and 10 showing the averaged results from experts and their normalized values and weights. The CR was found to be 0.068, as seen in table 11. This is slightly higher than other assessed indicators but still within the acceptable 10% limits. The rise in CR can be explained as the experts believe that the instructor's quality is crucial, creating a more favorable collaborative opinion towards the instructor's quality when compared to the other factors.

Table 9: Level 2 - operations evaluation

	Instructor's quality	Structured program	No. of Contact hours
Instructor's quality	1.00	2.667	2.00
Structured program	0.375	1.00	1.267
No. of contact hours	0.545	0.667	1.00
SUM	1.920	4.333	4.333

Table 10: Normalized table for level 2 operations evaluation

	Instructor's quality	Structured program	No. of contact hours	Weights
Instructor's quality	0.521	0.615	0.423	0.520
Structured program	0.195	0.231	0.346	0.257
No. of contact hours	0.284	0.154	0.231	0.223
SUM	1.00	1.00	1.00	

Table 11: Matrix adequacy parameters for level 2 - operation evaluation

Parameter	Value
CL	0.040
CR	0.068

5.1.2.3. Secondary indicators of the graduate

Graduates are the educational process's output, and the target of any educational program is to integrate them properly into society and the job market. On the second level below the primary graduate indicator, there are three contributing secondary indicators, that is; the percentage of graduates employed, the percentage of them employed in the engineering sector, and the average pay they receive post-graduation. From table 12 and table 13, it is concluded that the percentage of graduates employed, and the average pay are the most important secondary indicators respectively, followed by the percentage of graduates working in the engineering sector. The difference in weights between secondary indicators is marginal for this scenario. This may be because all three secondary indicators are important to the assessors. As seen in table 14 the adequacy of the matrix is intact, with a CR ratio of 0.09.

Table 12: Level 2 - graduate evaluation

	Percentage Employed	Percentage in Engineering	Average Pay
Percentage employed	1.00	2.167	0.867
Percentage in Engineering	0.462	1.00	1.033
Average Pay	1.154	0.968	1.00
SUM	2.615	4.134	2.900

Table 13: Normalized table for level 2 graduate evaluation

	Percentage Employed	Percentage in Engineering	Average Pay	Weight
Percentage employed	0.382	0.524	0.299	0.402
Percentage in engineering	0.176	0.242	0.356	0.258
Average Pay	0.441	0.234	0.345	0.34
SUM	1.00	1.00	1.00	

Table 14: Matrix adequacy parameters for level 2 - graduate evaluation

Parameter	Value
CL	0.052
CR	0.09

5.2. Assigning a value for the secondary quality indicators

After weighing each quality indicator against the other, the next stage in the AHP is to assign weights for each quality indicator in both types of programs; the Engineering program of UPEI, which adopts the PBL model, and the conventional engineering program. Different indicators were discussed earlier in section 4.2; however, the weight of each individual indicator will be assigned in this section. The obtained values for each quality indicator are a result of a survey with the same experts, the rationale behind the assigned values is discussed below. A summary of the weights is shown in table 16.

5.2.1. Availability of resources

The availability of scientific resources and references is crucial to building a robust curriculum. In the digital age, most resources are accessible, meaning that program structure or approach has no impact on this factor. However, for conventional programs, the transition between resources is seamless; They are easily connected. For a project-based program, this connection might be a bit lacking; this slight advantage for the conventional program is manifested in the rating of 1 for the conventional program and 0.8 for the project-based program. This might need to be revised as more resources become available for project-based learning schemes.

5.2.2. Maturity of the model

As the curriculum is tested and implemented for prolonged periods, it gets refined. This continuous improvement of the curriculum by practice fills the gaps and makes the curriculum stronger. From this perspective, the conventional program is also superior; conventional engineering programs have been taught for over 100 years, giving it a huge advantage. On the other hand, project-based programs like SDE are relatively new. The maturity of the curriculum is scored as per table 15.

Table 15: Maturity weighing scheme

Years taught	Score
1	0.1
3	0.2
5	0.3
10	0.4
15	0.6
25	0.8
25+	1

5.2.3. Market compatibility

Aligning curriculum with market needs offers a more substantial base for students, a student graduating from a program with an emphasis on the market will need less effort to blend into the workforce. In a project-based program such as SDE, the link with the industry is one of the program's core; this gives students enrolled in SDE a competitive edge. Usually, students work on an actual industrial project for an entire academic year in collaboration with an industry partner and under the supervision of a faculty member. In conventional engineering programs, this is sometimes done in the capstone project; however, it would be purely based on the instructor or the supervisor of the project to suggest an industry-linked project. Making it one of the fundamentals of the program offers a considerable advantage for project-based programs. Building on this analysis, the project-based programs were ranked as 1 while the conventional program ranked as 0.5.

5.2.4. Quality of instructor

The quality and expertise of the instructor are the basis of any academic activity; having the right set of skills and knowledge makes all the difference in the program quality and the delivered material to the students. In this study, it will be assumed that both programs have competent instructors, and both are given 1.

5.2.5. Program structure

Having a standardized process to follow usually offers less problems in implementation. For a project-based program to work, usually, a structured approach is utilized. Engineering design is a process rather than an intuition; in SDE and other project-based programs, engineering design is the core of the program, emphasizing the design projects as discussed in section 2. This is achieved by forming a centralized design committee to structure, link, map, and prepare the material across the four design clinics. Having a centralized committee formed from the design instructors make sure the connection between different years is not missed and, at the same time, doesn't undermine academic freedom as design instructors collectively agree on the mapping and content. The content is generic on the design process, ethics, project management, and engineering economics. However, extra content based on the nature of the project is independently developed by each instructor based on the project in hand. Other non-design courses are handled in the same manner as in any other conventional program, where instructors are given the course description, and its intended graduate attributes to fulfill the Canadian Engineering Accreditation Board (CEAB) requirements. The instructor then builds the curriculum independently and accordingly. Using this approach with interconnected and dependent courses with a clear needed outcome, such as the design courses, increase the efficiency of the delivery and decrease the risks of missing some of the important deliverables. Subsequently, in this area, the project-based program is given 0.8, and the conventional program is given 0.5.

5.2.6. Instructor contact hours with students

The amount of time spent is not always an indicator; however, more contact between the instructor and student help in the flow of information and the sharing of experience from the instructor to students. In a project-based environment where a yearlong industrial project is utilized, around 12 contact hours between the instructor and the students are available on a weekly basis. These also exclude extra office hours needed for individual projects. This is more than three times the contact hours between the instructor and students in a conventional engineering program. Accordingly, the project-based program was weighted in this area as 1, while the conventional program was weighted at 0.3.

5.2.7. Percentage employed

The ratio of graduates employed is an important indicator of the program's performance. From internal statistics, almost 100% of the project-based SDE graduates were employed in the first year. On the other hand, based on the Ontario engineers' report, around 80% find jobs in the first year. Accordingly, project-based programs are given 1 while conventional programs are given 0.8.

5.2.8. Percentage employed in engineering jobs

One of the issues facing engineering graduates is career shifts. Career shifts have several reasons, such as graduates losing hope of finding the right job in their field prominently. Another reason is the market saturation in some areas. Other areas, on the other hand, are facing issues with the lack of sufficient engineering graduates to fulfill market needs; this doesn't mean that not enough engineers are graduating, but it is an indication that Some graduates prefer to pursue other tracks due to the complexity of engineering jobs which they were not properly introduced to in the education phase. Statistics show that 28 to 60% of engineering graduates work in engineering depending on the province for conventional programs; for SDE, around 10% of the graduates seek post-graduate studies, and approximately 85% of graduates work in engineering; this shows that roughly only 5% conduct career shifts. Accordingly, project-based learning is given 0.95 and conventional program 0.4 for the weighting.

5.2.9. Average pay

Although this is an important indicator, sufficient data was not accessible and hence both programs will be given the same value of 1.

Table 16: Summary of factors relative weights

Indicator	Project Based Learning (PBL)	Conventional Program (CNV)
Resources	0.6	0.8
Maturity	0.4	1
Market Compatibility	1	0.5
Instructor quality	1	1
Structure of the program	0.8	0.5
Instructor-student contact hours	1	0.3
Percentage Employed	1	0.8
Percentage Employed in Engineering	0.95	0.4
Average Pay	1	1

5.3. Overall rank

The last step in the AHP process is to obtain the overall rank for each program scheme. To do so, the relative importance of the second level indicator obtained in section 5.1 by assessing factors against each other and the relative weight of the indicators obtained in section 5.2 are multiplied to get an overall rank of the second level indicator. The rank of the second-level indicators (secondary indicators) is then added together and multiplied by the importance level obtained in 5.1 of their corresponding first-level indicators (Primary indicators). This shows the overall rank of the first level indicator. Adding the ranks of the first-level indicators then gives the program's rank. These calculations are concluded in figure 4.

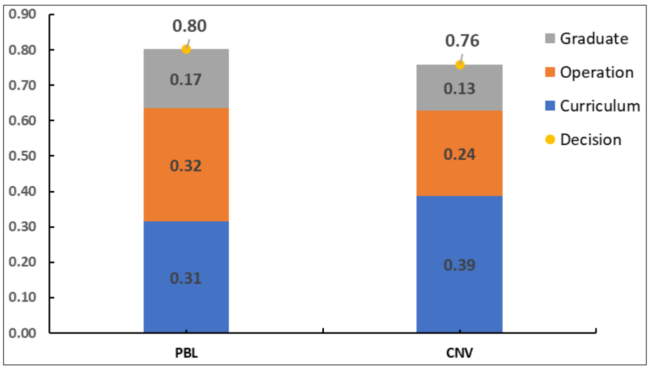

Fig 4: Overall rank of PBL and CNV

From Figure 4 it can be concluded that the overall rank of programs adopting the PBL model is slightly higher than that of the CNV program, with a difference of about 0.4. It is clear that the conventional program achieved a higher score in terms of the curriculum; this is mainly attributed to the availability of resources and the maturity of the program. However, it is expected that programs adopting the PBL model will become more popular this gap can be eliminated. Programs adopting a Project-based learning model, on the other hand, excelled in the operations; this is attributed to the more structured and evidence-based approach endorsed by such programs. The gap between programs decreases when it comes to the graduate, which can be attributed to the data insufficiency regarding the average pay of graduates from each program.

6. Conclusion

This work investigated the impact of project-based learning (PBL) on the quality of education compared to conventional learning. The PBL model was defined as a type of inquiry-based learning with a context provided through authentic questions and problems within real-world practices. Whereas the quality of education was identified based on three primary quality indicators; curriculum taught, operations within the program, and graduate. The curriculum was assessed based on the availability of sources, maturity of the curriculum reflecting iterative enhancements, and compatibility of the curriculum with the market. On the other hand, the operations within the program were assessed based on the instructors' quality, the operation's structure, and the direct contact between instructors and students transferring knowledge. Lastly, the graduates were evaluated based on the ratio of graduates employed, the ratio of these working graduates in the engineering field, and their average pay. The analytical hierarchy approach (AHP) was used to quantify the available data. Using this methodology, the relative importance of each quality indicator is assessed against the other quantitatively. This is done at two different levels, across primary and secondary indicators. The importance intensity is given a number based on a survey conducted in collaboration with four different instructors who taught in both programs and statistics from the Sustainable Design Engineering program of UPEI that adopts a PBL model. The adequacy of the model was verified using consistency ratio (CR) and consistency index (CI). The assessment on the first level of the primary indicators showed that curriculum and operation had more importance than the graduate as quality indicators. It can also be concluded that the curriculum had marginally more importance over the operations. The weight of each indicator was then assigned for each program. Programs adopting the PBL model showed an overall rank of 0.8, marginally higher than conventional programs, which is only 0.76. However, the main reason behind the slight difference is the curriculum, specifically the maturity of the curriculum. The PBL model is a new approach usually adopted by new young programs such as SDE, and hence the program's maturity showed a weak point. It can be concluded that PBL has considerable potential to be the primary teaching model through engineering programs. As time pass, the maturity of such programs will eventually get enhanced, graduating students that are fitting the market requirements. It is recommended that more data be collected and analyzed in future studies.

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