Quantitative Indicators for Assessing the Effectiveness of Project-Based Learning Experiences

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ABSTRACT

This paper reports on a comparison of four different Project-Based Learning (PjBL) experiences with the goal of identifying metrics that can be used to evaluate PjBL experiences for their effectiveness in achieving strong learning outcomes. Data is collected as part of a course taken by 40 engineering students at Shantou University, China with 20 students from the University of Calgary and 20 students from Shantou University. A combination of data sources are considered, with instructor observations, peer assessment, team grade and a question about the appropriateness of team size providing the most useful data for formulating an assessment of PjBL effectiveness.

KEYWORDS

project-based learning, design-implement experiences.

INTRODUCTION

The use of active learning methods, be it Problem-Based Learning (PBL) or Project-Based Learning (PjBL), are recognized as strong pedagogical techniques by which students are able to learn both the academic content as well as the professional skills required to function in their field of study [1]. PBL has been in use for over 40 years in fields that include medicine, engineering, science and economics [2]. The fundamental premise behind both PBL and PjBL is that real-life problems become the context in which students learn [1].

In the case of engineering education, the lifecycle of an engineering project provides an appropriate real-life situational context in which students can learn. The lifecycle of an engineering project can be characterized as the Conceiving, Designing, Implementing and Operating (CDIO) of a product, process, or system. The use of this lifecycle as the context for learning forms the basis of the CDIO Initiative [3]. An engineering education rich in the number and variety of these CDIO learning experiences will foster student development of both the engineering (academic) skills as well as professional skills [4].

A large number of references appear in the literature comparing both PBL experiences [5,6,7] and PjBL experiences [8] with standard lecture-based instruction. The references are part of a long ongoing debate among educational researchers over the pedagogical gain derived from the use of these active learning methods [7,9]. The majority of the investigations involve comparisons of a control group that receives standard lecture-based instruction with an experimental group that receives either PBL or PjBL experiences. Evaluations comparing control and experimental groups are performed using indicators that include performance on standardized tests, gains in problem solving capabilities, understanding of the subject matter using pre- and post tests, gains in understanding of specific skills or strategies, and changes in group problem solving and work habits [8].

Although there are many positive aspects surrounding PBL and more specifically PjBL for engineering programs, the fact remains that these experiences can be expensive to implement given the requirements for non-traditional hardware and infrastructure, the additional expenses required for project materials and supplies, and the additional instructor time required to prepare, run, and assess these activities. In light of this, it is desirable to have quantitative measures or indicators that can be used to rate the effectiveness of a particular PjBL experience. The goal of this paper is to explore a number of different quantitative indicators in an effort to identify those indicators that can be used to evaluate the effectiveness of a PjBL experience.

Research Questions:

The current investigation compares one PjBL experience with other PjBL experiences, unlike earlier investigations that involved quantification of the effectiveness of PjBL in comparison to standard lecture-based instruction. This is done in an effort to first determine the relative level of effectiveness of a particular PjBL experience, and second to attempt to identify indicators that quantify the effectiveness of PjBL experiences. These indicators can then be used by engineering educators to determine the value in repeating a particular learning exercise more than once.

BACKGROUND

Four PjBL experiences involving Renewable Energy are compared in this paper. The PjBL learning experiences were taken as part of a course entitled Renewable Energy Practicum, a one-month long course taken in May 2011 by 20 University of Calgary (SSE) engineering students and 20 Shantou University (STU) science and engineering students. The SSE students were enrolled only in the two courses during the program for which they receive credit for two semester-long technical elective courses, while the STU students took the two courses in addition to their normal course load. Course instruction was at Shantou University and delivery was in English.

All of the PjBL exercises included both a build phase (Implement) and a test phase (Operate). The exercises consisted of: i) construction and testing a solar-photovoltaic cell [10]; ii) construction and testing a solar fan [11]; iii) construction and testing of a wind turbine [12]; and, iv) construction and testing of a solar-thermal water heater [13]. Each implement-operate exercise was taken from the project-sharing website Instructables (www.instructables.com) [10-13].

The Instructables website provides step-by-step instructions on how to build a wide array of devices, and the projects selected provide a good starting point for PjBL exercises that last anywhere from 2 to 12 hours each. Students were provided with the recommended materials and supplies for each project, and allowed to improve/modify the design with **a** few restrictions. One restriction was to limit access to additional materials out of fairness to the other project teams, thereby ensuring that each team was operating in a similar-resourced environment.

Project Descriptions:

1. Solar Photovoltaic Cell: this project involved fabrication and testing of a copper-cuprous oxide photovoltaic cell. A copper plate heated on a hot plate resulted in the formation of a fine cuprous-oxide layer on the surface of the copper plate. The plate was then mounted in a case filled with a water / baking soda mixture. An electrical circuit was completed through the addition of a second copper plate, with the completed cell shown to the left in Fig. 1. This project was relatively simple and provided an introduction for the students to both the workshop and the nature of the implement-operate projects.

Learning Outcomes: mechanical design; photo-voltaic effect in a copper-cuprous oxide thin-film solar cell; simple soldering; experimental method.

Figure 1: Solar Photovoltaic Cell (left) and Testing of the Cell (right)

2. Solar Fan: this project involved the use of two solar cells and two NiCd batteries (1.2V and 600 mAh) from commercial solar garden lights. The solar cells were used to charge the batteries during the day, and at night the charged batteries were used to power a 12 V (0.15A) computer fan. Use of two 1.2 V batteries to power a 12 V fan requires the use of a Linear Technologies micropower DC/DC converter (LT1073). The circuitry and fabrication in this project was more complex than the first project, requiring the students to be both organized and focused. An example of a final system is shown to the right in Fig. 2.

Learning Outcomes: mechanical design; energy storage; power conditioning; soldering techniques; circuit assembly; experimental method.

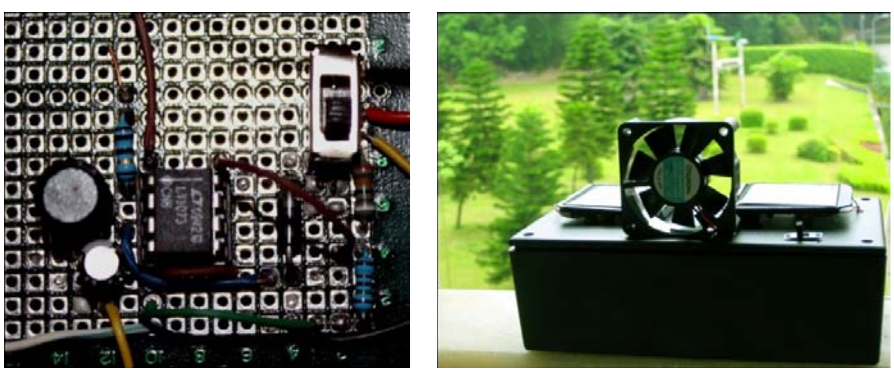


Figure 2: LT1073 DC/DC Converter circuit (left) and Solar Fan project (right)

3. Wind Turbine: this project involved the fabrication and testing of a vertical-axis wind turbine of the Savonius rotor design. The most complicated aspect of this project involved the fabrication of the electrical generator. Eight rare-earth Neodymium permanent magnets (NdFeB) were mounted to the rotating Savonius turbine, and twelve generator coils were fabricated by winding aluminum bobbins using either 32 AWG or 36 AWG magnet wire. This project proved to be the most challenging due to the electrical generator section and the

turbine bearing system. Placing it during the third week was optimum as students had honed both their mechanical and electrical skills in the two previous projects. Testing was performed at speeds up to 10 m/s in the Shantou University wind tunnel laboratory (3 m X 2 m test section; 45 m/s max velocity), as shown in Fig. 3.

Learning Outcomes: mechanical design, wind turbine power curve; AC generator design; rectification of an AC voltage to a DC voltage; power estimation; experimental method including test plan development.


Figure 3: Operating wind turbine (left) and students in the STU Wind Tunnel (right)

4. Solar-Thermal Water Heater: this project involved the fabrication and testing of a solar-thermal water heater that mimicked the performance of an evacuated tube collector. Students fabricated the water heater using nested plastic bottles. Reflective tape was used to increase the concentration ratio of the collector. A simple child thermometer was used to measure the temperature of the water within the heating section, as shown to the right in Fig. 4. This was the simplest project and it was placed at the end of the course during the week with the least amount of time for a project. The students were skilled in the use of equipment in the workshop by the final week (high-speed rotary cutting tool, hand drills, hand-operated shearing tools, soldering, etc.) and consequently the build phase of the project was completed on the first day.

Learning Outcomes: mechanical design; solar-thermal energy systems; experimental method.


Figure 4. Solar-thermal water heater designs (left) system testing (right)

METHODS

This section discusses the nature of the student sample, the instruments and measures used, and the procedures by which the instruments and measures were delivered to the student sample.

Sample:

Students from both the University of Calgary and Shantou University applied to take the one-month long Renewable Energy Practicum course (along with a second Innovation and Entrepreneurship in Renewable Energy course not described in this paper). University of Calgary students were selected based on a number of factors that included year in program, (third-year [Junior] students receiving preference), letter grade in an earlier Thermodynamics course, and student responses in the program application that included questions like “Reasons for wanting to participate in the program” and “What do you expect to gain by participating in this program?” Shantou University students were selected based on their field of study, their year in the program (third-year students receiving preference), and their English language abilities, an important prerequisite given that all course instruction was provided in English.

Students worked on projects in teams of 5 students per team. Group assignments included at least one female student member per team and a minimum of at least two students from either SSE or STU on each team. Student teams were determined randomly at the start of each project. Although information about student personality was known, it was not used during the team formation process.

Instruments and Measures:

1) Instructor Observations

The instructional team was in the laboratory during scheduled laboratory periods, amounting to approximately 26 hours of student observations. Instructor observations were recorded daily in a journal and used to infer aspects of the PjBL experiences that were difficult to capture with the other instruments. Examples of instructor observations included the distribution of work within a team, the level of intensity of student activity, the need to force students out of the lab at the conclusion of a 4-hour laboratory session, and the occurrence of euphoric outbursts when a group of students would solve a challenging problem. Other observations included taking note of students who appeared to be either high or low achievers and the amount of peer instruction taking place during a particular project.

2) Project Execution

Each project was characterized based on a number of factors that included the number and complexity of steps, the amount of time allocated for each project, the ability to test / realize the goal of the project, the cost of materials per project, and the quality and availability of the required infrastructure.

3) Team Project Review Survey

In order to quantify the PjBL learning process, a short (11 question) survey shown in Fig. 5 was developed. This survey was completed by students at the end of each one-week long PjBL experience. It was used to report on the level of difficulty of each step of the exercise, the level of student involvement (number of tasks per team member), the level of learning associated with non-technical attributes, and the level of learning associated with technical attributes. A second paper [14] examines the PjBL experiences in further detail including the influence of cultural norms / differences between the two student groups.

Questions 1-3 and 9 focus on the level of difficulty of each step of the exercise. These questions do not assess the level of difficulty directly, but instead ask students to quantify their level of activity on the project. “Level of difficulty” is very subjective and would vary from student to student based on their background as well as on how project tasks were shared among team members (e.g., more skilled team members may be assigned the most difficult tasks). However, by linking back to the number of steps involved in a given project, a relative level of activity per step can be translated into a level of difficulty for the project.

Questions 2 and 3 examine the level of involvement of students in a team setting. Rather than asking students to quantify the “number of tasks per team member”, we chose to quantify a more general “level of involvement." That is, asking students to quantify the number of tasks completed would have overly complicated the survey and would have likely proven to be unreliable (e.g., difficult for students to identify what constitutes a task). The more general questions on each student’s contribution to the team, in combination with the instructor’s knowledge of the number of steps for the project, result in a more reliable estimate of the level of involvement for individual students. This, in combination with student feedback on team size (Q 9), provides insights into the level of difficulty of each project (e.g., more difficult projects require more students).

The level of learning associated with technical and non-technical attributes is addressed by Questions 4-6: Questions 4-5 focus on new skills, while Q 6 focuses on the mode of learning (i.e., PjBL vs. traditional lecture notes and textbook). For this portion of the survey, Questions 4-5 are linked directly to the intended learning outcomes for each project. For example, the Wind Turbine project performed by the SSE / STU students involved electric generators and full-wave rectifier circuits. Although the basic theory should not have been new to the students, the PjBL exercise led some students to new insights into power losses in practical electrical circuits. However, when viewing the survey results in the context of the project learning outcomes and the classroom assessments (e.g., team presentations and answers to questions), it became clear when and where new technical and non-technical attributes were gained for the project.

SCHULICH School of Engineering

Team Project Review Survey - Spring 2011

Backround Information: Age __________ Male ☐ Female ☐ University ______________

Team project review:

For each statement, select a number from 0% to 100% to indicate your degree of agreement with the following statements (please check one response for each statement).

How strongly do you agree with the following statements:	**Disagree** 0%	25%	50%	75%	**Agree** 100%
1 My level of activity on this project was high.	☐	☐	☐	☐	☐
2 I made important contributions to my team.	☐	☐	☐	☐	☐
3 My team's project would not have been completed on schedule if I had been absent.	☐	☐	☐	☐	☐
4 I learned new non-technical skills (e.g., communication, team work, etc.)	☐	☐	☐	☐	☐
5 I learned new technical knowledge in the specific project area.	☐	☐	☐	☐	☐
6 This project helped me understand the technical area in greater detail than if I had only been exposed to lectures, read a textbook and solved questions in the textbook.	☐	☐	☐	☐	☐
7 This project helped me understand the technical area in greater detail than a traditional laboratory exercise would have.	☐	☐	☐	☐	☐
8 This projected helped me see the relevance of previous course work.	☐	☐	☐	☐	☐
9 Our team had the right number of students for the scope and alloted time.	☐	☐	☐	☐	☐

Based on your answer to statement 9, please indicate how many more or less team members you fee your team needed (please only answer 10a or 10b).

	1	2	3	4	5
10a My team needed ## more members.	☐	☐	☐	☐	☐
10b My team needed ## fewer members.	☐	☐	☐	☐	☐

Figure 5. Team Project Review Survey

4) Personality Types

Two different personality tests were administered during the course. The first was a relatively simple test [15] that describes attributes of four different personality types (described by the colors Red, Blue, Green and Yellow) and participants were then asked to select the one that best described them:

RED:	*Just Get It Done* people. What you see is what you get.
BLUE:	*Let's Do It Better* people. Visionaries with strong leadership qualities.
GREEN:	*Let's Experience it All* people.
YELLOW:	*Let's All Get Along* people. Caregivers and Peacemakers.

A second personality test was administered based on a modified version of the Meyers-Briggs Type Indicator [16]. Given the simplicity with which the Red/Blue/Green/Yellow personalities can be presented and remembered by the students, it was used extensively in the course and for all of the results presented in this paper.

5) Peer Assessment

Students were asked to complete a peer assessment survey at the conclusion of each PjBL experience [17]. The peer assessment asks students to self assess as well as evaluate their peers on participation, leadership, listening, feedback, cooperation, and time management. These results were then combined for each student and used as a percentage of their final grade (5% per PjBL experience). Students were provided with the averaged results of how their peers evaluated their performance.

6) Team Performance (Grade)

Student team performance was quantified based on delivery of a group presentation (5% per PjBL experience) as well as a written assembly / test document (10% per PjBL experience). Rubrics were used for the grading of both the team presentations as well as the team document.

Procedures:

Each of the four PjBL experiences lasted for approximately one week. Each week began with a lecture that introduce**d** students to the project, distribution of team assignments, and information pertaining to areas of safety for that particular project. Laboratory sessions typically lasted for four hours during which students could work on building their system, testing their system, or development of the course deliverables (presentation and assembly / test document). On the final day of the week, students presented their projects in 15 minute presentations (10 minutes presentation, 5 minutes questions and answers). At the conclusion of each project, students were given the peer assessment survey as well the team project review survey. In order to comply with requirements for research involving human subjects, the results of the team project review survey were not released to the course instructional team until after the final grade had been determined and submitted.

RESULTS AND DISCUSSION

Instructor Observations and Project Execution:

The budget, number of steps, hours to complete, lab overtime requests and euphoric outbursts for each project are listed in Table 1. For Project 1 (Solar PV) it was sunny during the testing period and thus students were able to obtain data. This was not the case for Projects 2 and 4 for which it was not sunny during the test period. For Project 3 (Wind

Turbine) testing was conducted in the wind tunnel and thus atmospheric conditions did not influence project results. The lack of ability to collect test data for Projects 2 and 4 placed these projects at a slight disadvantage when compared to Projects 1 and 3.

Table 1
Project Budgets, Number of Steps and Hours to Complete

Project	Materials Cost ($ / team)	Number of Steps to Complete	Hours to Complete Project	Lab Overtime Requests	Euphoric Outbursts
1. Solar Cell	$0.81	13	4	None	Few
2. Solar Fan	$42.87	11	8	Some	Some
3. Wind Turbine	$108.40	18	10-12	Often	Many
4. Solar Thermal	$2.17	11	2	None	None

Summarized Survey Results (SSE / STU):

Tables 2 and 3 show the summarized results of the Team Project Review Survey for those that responded either 75% or 100% in agreement with each question. Table 2 shows responses to questions that involve team performance and team size, while Table 3 shows responses to questions that involve learning outcomes. Highlighted table entries denote SSE responses in excess of 80% for Q6, Q7 and Q9.

Table 2
Contributions to Team Performance (Survey Q1-Q3, Q9 - 75% and 100% Responses)

Project	Q1 – Activity Level (SSE / STU)	Q2 – Important Contributions (SSE / STU)	Q3 – Impact of Presence (SSE / STU)	Q9 – Proper Team Size (SSE / STU)
1. Solar Cell	100% / 63%	100% / 63%	79% / 21%	85% / 95%
2. Solar Fan	89% / 65%	100% / 75%	95% / 65%	53% / 84%
3. Wind Turbine	100% / 83%	100% / 72%	83% / 59%	89% / 78%
4. Solar Thermal	100% / 60%	95% / 60%	80% / 53%	35% / 73%

Table 3
Quantification of Learning Outcomes (Survey Q4-Q7 - 75% and 100% Responses)

Project	Q4 – Non-Technical Skills (SSE / STU)	Q5 – Technical Skills (SSE / STU)	Q6 – PjBL vs Lecture / Textbook (SSE / STU)	Q7 – PjBL vs Traditional Lab (SSE / STU)
1. Solar Cell	75% / 100%	75% / 89%	80% / 95%	65% / 95%
2. Solar Fan	53% / 90%	58% / 85%	63% / 90%	53% / 90%
3. Wind Turbine	72% / 83%	67% / 89%	83% / 94%	83% / 89%
4. Solar Thermal	45% / 73%	35% / 73%	50% / 93%	55% / 93%

Team Project Review Survey:

Figure 6 indicates that the percentage of students agreeing that they learned non-technical skills, as reported by indicating either 75% or 100% on Question 4 of the Team Project Review Survey, was 87%, 72%, 78%, and 57% on Projects 1, 2, 3, and 4 respectively. It is suspected that the strong results for Project 1 (Solar PV) were partially attributable to the novelty of the experience, given that this was the first experience for the students in the course. It is also possible that the Hawthorne effect may have had an impact, with the mere presence of a data collection process having a positive impact on the results. This impact was, however, reduced on subsequent projects as the effect began to wear off.

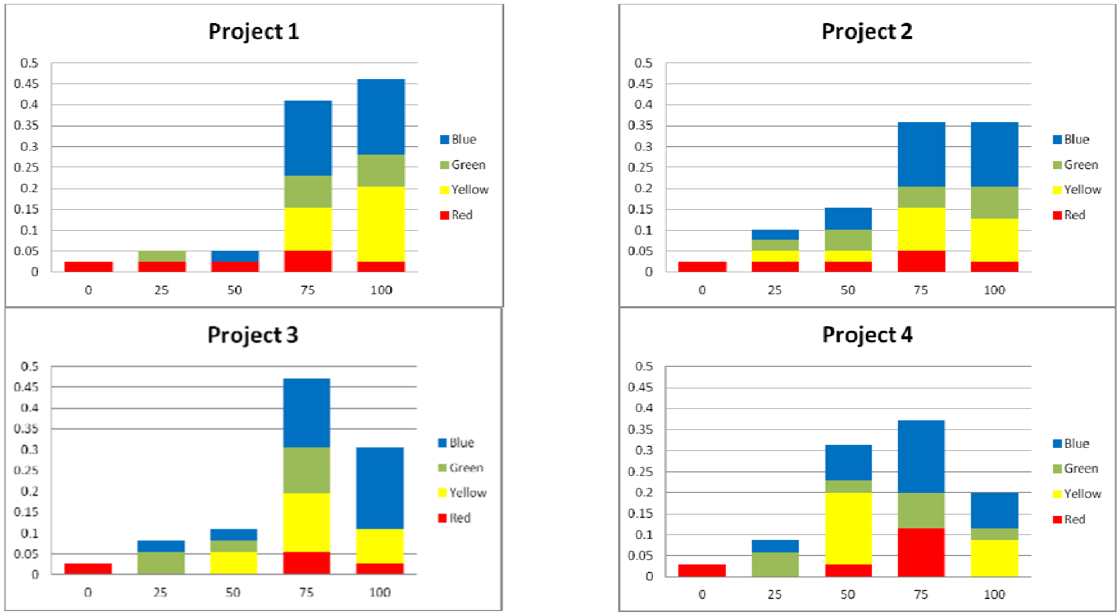


Figure 6. Non-Technical Skills Development (Survey Question 4)
(Vertical Axis: Probability Density; Horizontal Axis: Project Review Survey Response)

Figure 7 shows technical skills development for each of the four PjBL experiences. The percentage of students agreeing that they learned technical skills, as reported by indicating either 75% or 100% on Question 5 of the Team Project Review Survey, was 82%, 72%, 78%, and 51% on respective Projects 1, 2, 3, and 4. These results are very similar to the results obtained for non-technical skills in Fig. 6.

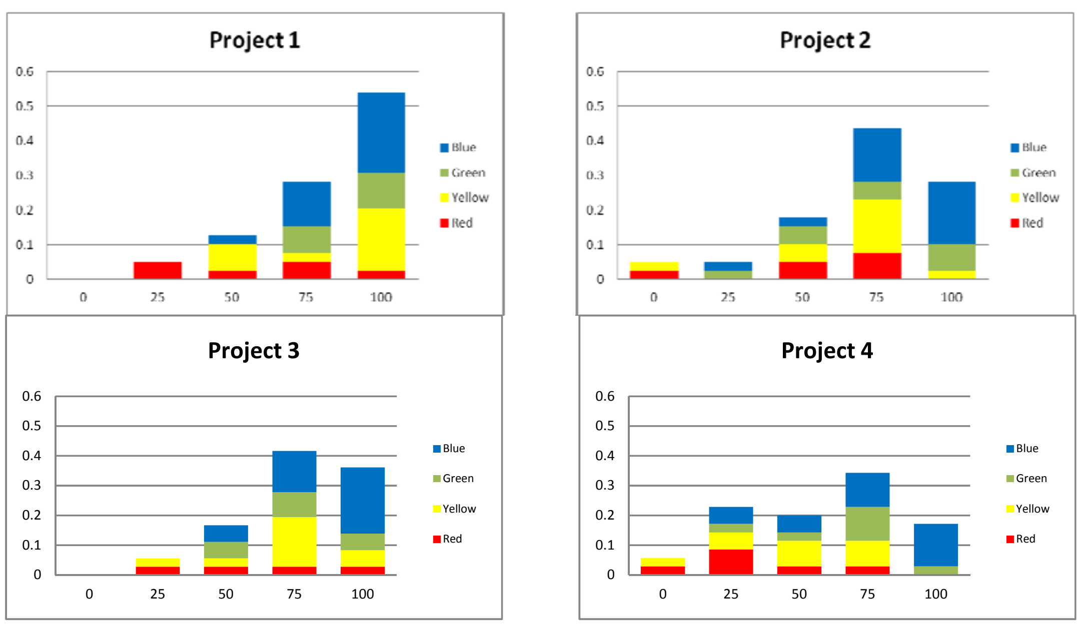
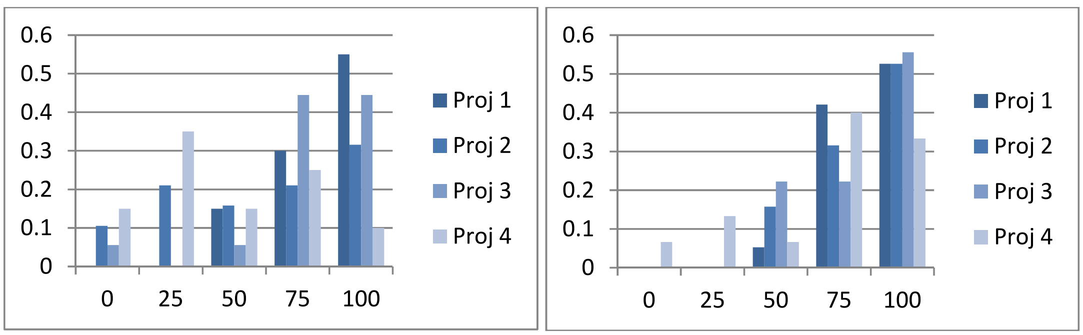


Figure 7. Technical Skills Development (Survey Question 5)
(Vertical Axis: Probability Density; Horizontal Axis: Project Review Survey Response)

Student personality has been identified in both Figs. 6 and 7 in an effort to examine if personality types had an influence in student reporting of skills gained. For Projects 1, 2, and 3 the BLUE students tend to report the greatest amount of both non-technical and technical learning.

The results of Project Review Survey Response Question 9 "Our team had the right number of students for the scope and allotted time" is shown in Fig. 8. It is observed that the STU students were more likely to respond that their team was properly sized than the SSE students. For Project 1, 85% of SSE students and 95% of STU students indicated either 75% or 100% on Question 9. For Projects 2, 3, and 4 the respective SSE/STU results were 53% / 84%, 89% / 78%, 35% / 73%, as shown in Table 3.

There are two factors influencing these results. One factor is that the STU students were taking a full course load in addition to the course reported in this paper and consequently they had less time to contribute to the projects, leading the SSE students to report that fewer students were required on three of the four projects. The other factor influencing these results was that the projects themselves varied in difficulty, with Project 3 being the most difficult.



SSE Students STU Students

Figure 8. Properly Sized Teams (Survey Question 9)

Peer Assessment:

It was possible to further examine how students felt about their team size by comparing survey Question 9 to the Peer Assessment Average for each team. The peer-assessment average has a maximum of 5 points, with a value of 5 indicating high team functionality. Data plotted for each project in Fig. 9 (left) indicates that students were most content with their team size for Projects 1 and 3, and least content with team size for Project 4. The standard deviation of the response to Question 9, plotted in Fig. 9 (right), indicates the level of agreement among team members (low standard deviation indicates strong agreement among team members) with the strongest agreement occurring for Projects 1 and 3 and the weakest agreement for Projects 2 and 4.

Figure 9 (right) indicates that teams with the least internal friction (high average peer assessment value) tended to also be the most satisfied with the size of their groups. As the average value of peer assessment decreased, so did satisfaction with group size. There are a number of reasons why Projects 1 and 3 have the higest score on both dimensions, including project complexity and the fact that students were able to test their final designs. In the case of Projects 2 and 4, both solar energy projects, it was difficult to conduct final testing due to the fact that it was not sunny during the testing period. It is believed that the inability to test was one factor that led to student frustration, resulting in the observed amplification of team conflict.

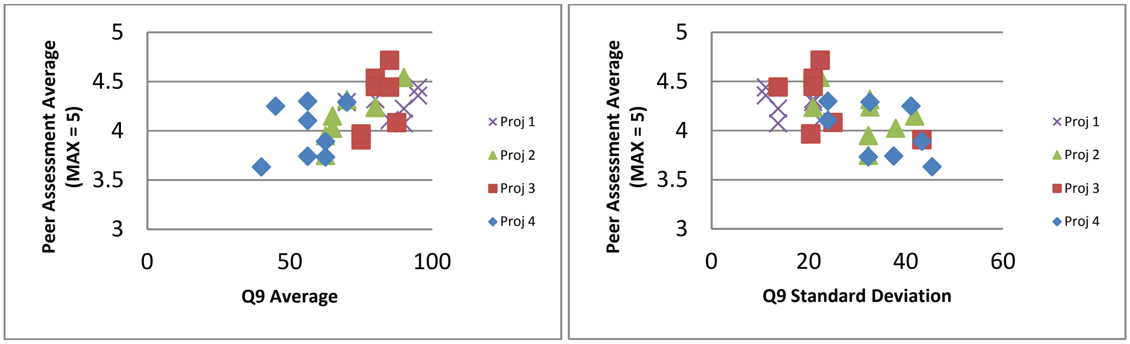


Figure 9. Peer Assessment versus Survey Question 9
(left: Q9 Average; right: Q9 Standard Deviation)

Peer Assessment distribution can also be used to examine team functionality, as illustrated in Fig. 10. Projects 1 and 2 show a very similar distribution, while Project 3 shows a top-hat distribution, presumably due to the high level of intensity of the project. Project 4 returns to a skewed distribution, only now with a shift of students towards lower peer assessments due to the conditions of the project (not challenging, inability to conduct testing).

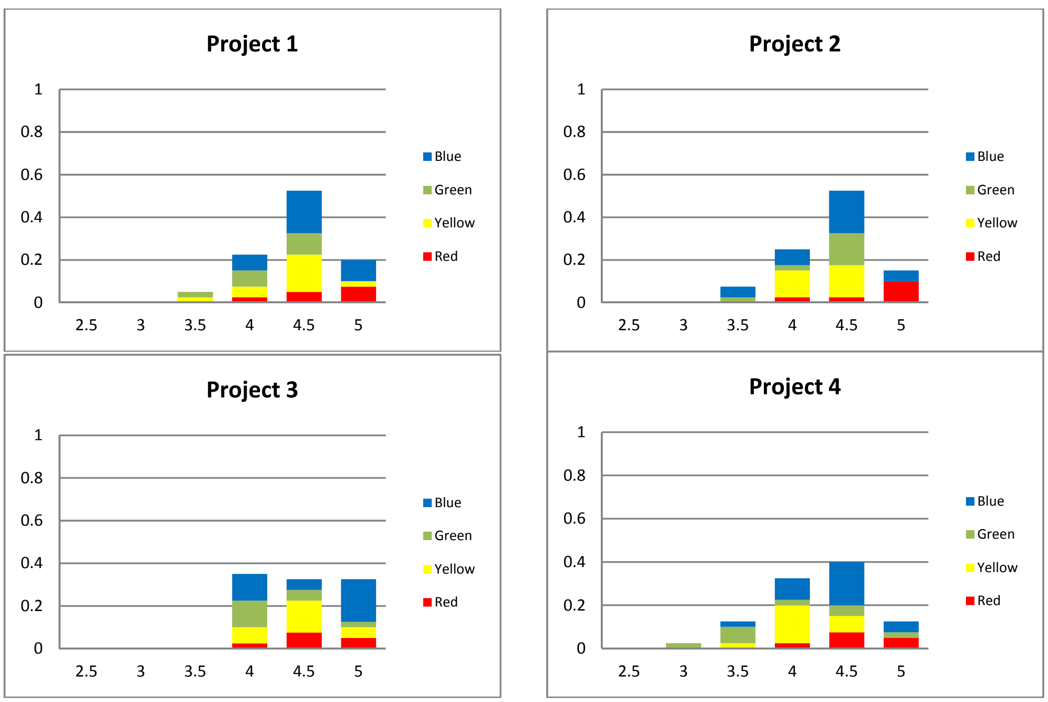


Figure 10. Peer Assessment Distribution with Project
(Vertical Axis: Probability Density; Horizontal Axis: Peer Assessment Scale 0-5)

Project Grade:

The nature of the PjBL experiences were further examined by comparing the team grade (oral presentation and written assembly / test document) with the peer assessment value for each team member, as shown in Fig. 11. In the Instructor's opinion, given that Projects 1 and 4 were the easiest to perform, these projects did not challenge the teams resulting in the scatter present in the plot to the left in Fig. 11. Projects 2 and 3 were more challenging, and consequently the teams were strained in a manner that enabled well-performing teams to score higher on both the written report and the oral presentation, resulting in what approximates a linear relationship as indicated in the plot to the right in Fig. 11.

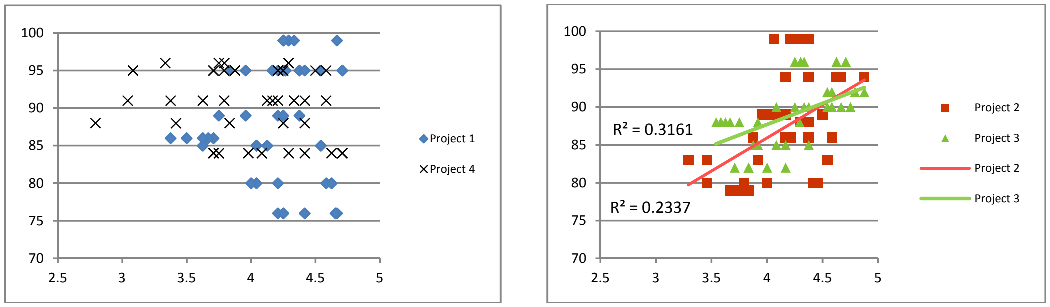


Figure 11. Team Functionality - Project Grade versus Peer Assessment (Vertical Axis: Project Grade; Horizontal Axis: Peer Assessment Scale 0-5)

Grade distribution for all students is shown in Fig. 12. It is interesting to note that BLUE students tend to report having learned a great deal of non-technical and technical knowledge (Figs. 6 and 7), yet they are not able to achieve the highest grades (combined oral presentation and written report) as reflected by the project grade distribution in Fig. 12. This is most likely explained by BLUE students becoming engaged in the PjBL exercise, but less interested in the reporting aspects (presentation and written document).

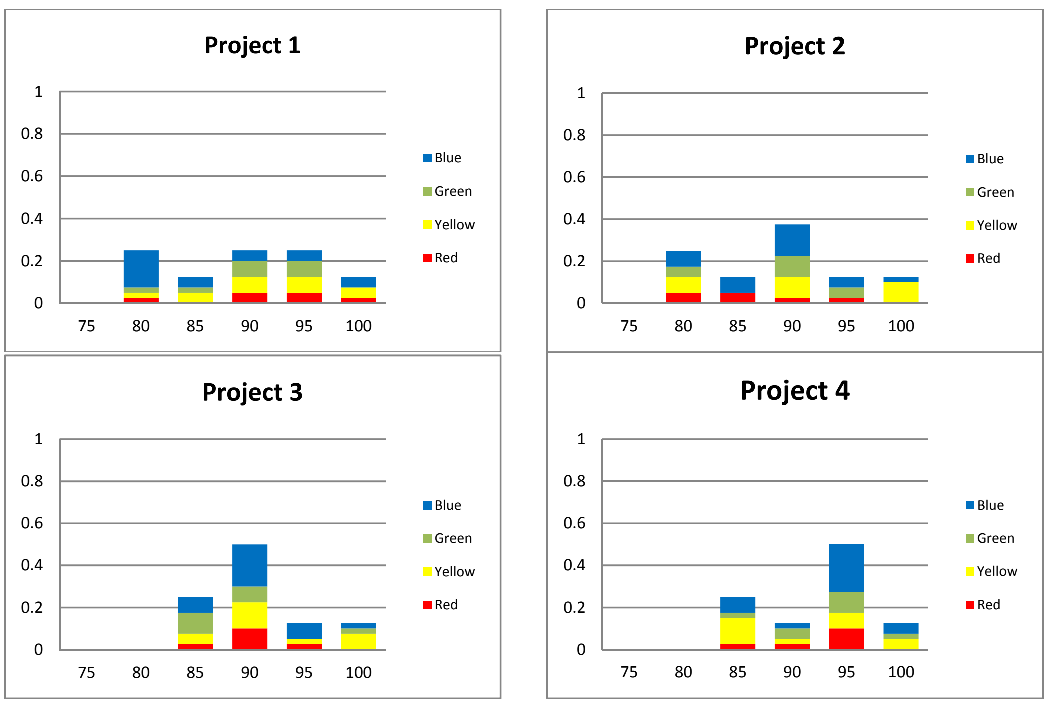


Figure 12. Project Grade distribution with Project (Vertical Axis: Probability Density; Horizontal Axis: Project Grade)

Figure 13 shows the four-project average grade for each student plotted as a function of their four-project average peer assessment value. This indicates that outliers can skew the grades of their teammates, as indicated by the two circled data points. The plot reveals the presence of outlier students, notably one student with an extremely high average (Grade 97%, Peer 4.25), and another with a very low average and low peer assessment value

(Grade 84%, Peer 3.4). Student teams consisting of the strong student would benefit from that student's presence on the team.

Final grade obtained in both the oral presentation as well as the written assembly / test document was found to be a poor indication of project effectiveness. It was found that the highest combined grade was always attained by the team that had the strongest student. Consequently this provided an indication that it was possible for the contribution of the one strong student to outweigh other factors, and thus a final team-based grade does not appear to be a reliable measure of team learning outcomes.

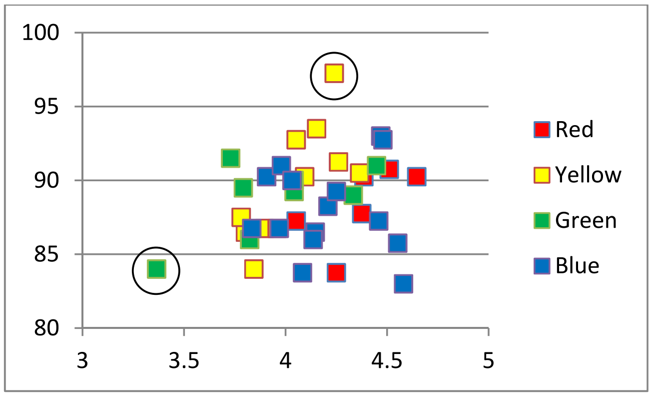


Figure 13. Project Grade (Vertical) versus Peer Assessment Scale (Horizontal)

CONCLUSIONS

The results of this paper demonstrate the challenges and complexity in trying to develop indicators for identifying the effectiveness of PjBL experiences. Factors as diverse as the inability of students to realize the final testing goal of a PjBL experience to the presence of a high-achieving student can create a bias to both student survey results as well as team grades. Consequently a hybrid approach has been adopted whereby different input measures have been used to determine effectiveness. These measures include instructor observations, project execution, student surveys, personality types, peer assessment, and team grade.

The findings of this paper indicate that instructor observations, a survey question addressing the appropriateness of team size, peer assessment results and team grade are the most useful data sources for indicating the effectiveness of one PjBL experience when compared with other PjBL experiences.

The results also indicate a number of important factors that influence the effectiveness of PjBL experiences. These include the ability to realize the final outcome of the project either through testing or some other demonstration. The inability to realize the outcome of a project results in the reporting of a negative learning experience by students. Furthermore, even though the students may actually have learned a great deal, they failed to acknowledge or accept this. In addition, the project needs to be sufficiently complex so as to keep all of the team members engaged in some aspect of the project at all times. Ideally a project will involve subsystems that can be distributed among team members thereby ensuring that activities progress in parallel.

With respect to final team grade, care needs to be taken when using this final team grade to assess the value of a particular PjBL experience. This is due to the fact that outlier students can bias the results of the final grade, making it difficult to assess whether or not it was a team performance or an individual performance. Moreover, it was found that when the team score was plotted against the individual peer assessment score, the most challenging projects revealed what appeared to be a linear relationship whereas the more simple projects only revealed random scatter. Overall, a question about the appropriateness of team size followed by instructor observations were the most useful measures for determining the effectiveness of a particular project. Other measures included peer assessment and team grade, provided that these measures were used in combination with other measures.

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