STUDENT LEARNING AND SELF-EFFICACY IN PROJECT-BASED LEARNING

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ABSTRACT

In this paper we investigate the relationship between student learning and self-efficacy in a multicultural project-based learning course. The study is based on indirect and direct assessments of student learning during a four-week renewable energy practicum at Shantou University. The results show that better alignment is needed between the various forms of assessment used in PjBL courses and the teaching and learning activities associated with the course.

KEYWORDS

Project-based Learning, Self-efficacy, Graduate Attributes Assessment.

INTRODUCTION

In this paper, we report on the relationship between student learning and self-efficacy in a multicultural Project-based Learning (PjBL) course. The study was conducted as part of a four-week course on renewable energy in the spring of 2012 at Shantou University, and extends our spring 2011 investigation of student self-efficacy and its relationship to student mastery of fundamental engineering skills same course [1].

In this study, we combine self-efficacy survey results with direct, in-class assessments to explore the relationship between perceived knowledge and demonstrated understanding. The self-efficacy survey was performed at the start and end of the course, and focuses on fundamental graduate attributes identified by the Canadian Engineering Accreditation Board (CEAB) [2]. In-class assessments were in the form of a series of multiple-choice exams that were performed at the end of each project to assess students' understanding of the background readings for the projects and their observations during the project sessions.

We begin this paper with background on the PjBL course and the assessments used for this study. Next we compare the results of the self-efficacy surveys with those of the post-project exams by focusing on three graduate attributes that link most closely to the PjBL course learning outcomes. We conclude with our observations from this study as well as recommendations for future studies of this nature.

BACKGROUND

The PjBL course that is the focus of this paper is one of two courses on renewable energy that are offered over a one-month period each spring at Shantou University. The courses are taught to a group of 20 Canadian students from the Schulich School of Engineering (SSE) and 20 Chinese students from Shantou University (STU): the students are primarily in their third year of study (juniors), however some fourth year (senior) students also participate in the course. In this section we provide a brief overview of the PjBL course, followed by a description of the self-efficacy and exam assessments that were used for this study.

The Project-based Learning Course

The PjBL course, "Renewable Energy Practicum", consists of four implement-operate exercises, performed by teams of 5 students over a four-week period (i.e., approximately one project per week). Each project included both a build phase and a testing phase, and was supplemented by course readings and field trips (two field trips over the four-week period).

The exercises consisted of: (1) construction and testing a solar-photovoltaic cell, (2) construction and testing a solar fan, (3) construction and testing of a wind turbine and, (4) construction and testing of a solar-thermal water heater. Each implement-operate exercise was taken from the project-sharing website Instructables (www.instructables.com), which provides step-by-step instructions on how to build a wide array of devices. More details on each of the implement-operate exercises can be found in [3].

At the beginning and end of the course, students were requested to complete a 38-question survey, described in the next subsection, that required them to reflect on their abilities in core engineering competencies. In order to ensure that all students understood the fundamental material associated with each project, students also completed a short multiple-choice exam at the end of each of the four projects (described at the end of this section).

The Self-efficacy Survey

As noted previously, the self-efficacy survey used for this study focused on the Canadian Engineering Accreditation Board's (CEAB) twelve graduate attributes [2]. In 2008, the CEAB updated their criteria and procedures, moving toward a model that emphasizes continuous improvement, and more specifically, program outcomes. Under these new criteria, Canadian engineering programs are required to assess student graduate attributes in the following twelve general areas, and demonstrate that a process is being followed to continuously improve the programs.

3.1.1 A knowledge base for engineering
3.1.2 Problem analysis
3.1.3 Investigation
3.1.4 Design
3.1.5 Use of engineering tools
3.1.6 Individual and team work
3.1.7 Communication Skills
3.1.8 Professionalism
3.1.9 Impact of eng. on society & environ.
3.1.10 Ethics and equity
3.1.11 Economics and project management
3.1.12 Life-long learning

Although the majority of these attributes can be developed in a project-base learning context, we focused on three specific graduate attributes in this study [2]:

> *3.1.1 A knowledge base for engineering*: Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.
>
> *3.1.3 Investigation*: An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.
>
> *3.1.5 Use of engineering tools*: An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.

These graduate attributes were chosen since they are most in-line with the learning activities and assessments used in this particular PjBL course: i.e., background readings and discussions on renewable energy (i.e., 3.1.1 "a knowledge base for engineering"), project build and test activities (i.e., 3.1.3 "investigation" and 3.1.5 "use of engineering tools").

In order to demonstrate that graduates of an engineering program possess these general attributes, each graduate attribute was expanded into a set of indicators that "describe specific abilities expected of students to demonstrate each attribute" [2]. In addition to providing a means of obtaining evidence to determine if the attribute has been achieved, the indicators had to be acceptable within the context of the program's educational objectives, as well as understood and meaningful to those involved in the assessments (e.g., faculty, students, alumni).

We describe the general process that was followed to develop this set of indicators in [4]. For this paper, we use the survey that was developed for indirect assessment of the twelve graduate attributes. In this survey, each graduate attribute is addressed by three to four questions that were formulated from the set of indicators.

All questions were posed in the form of "how confident are you in your current ability to …", and students were required to rate their confidence on a five-interval scale ranging from 0% "no confidence" to 100% "total confidence" (in 25% intervals). For example, three survey questions corresponding to the three graduate attributes that are the focus for this study are:

> How confident are you in your current ability to:
>
> - use your technical knowledge to participate in a design discussion (3.1.1 "A knowledge base for engineering")
> - synthesize information to reach conclusions that are supported by data and needs (3.1.3 "Investigation")
> - describe the limitations of various engineering tools and choose the best one to accomplish a task (3.1.5 "Use of engineering tools")

The full set of survey questions are provided in [1].

The survey involved the entire class of 40 students (20 Canadian students from SSE and 20 Chinese students from STU) and was performed at the start of the course and four weeks later at the end of the course. When introducing the survey to the class, it was described as a "survey on engineering competencies developed to date": responses should reflect students' belief in their ability to succeed in the specific situations described in the survey. Both instances of the survey were paper-based, and students were given sufficient classroom time to complete the survey. In the next section, we summarize the results of the surveys.

In-class Assessments

After each build-test activity, we ran a short exam (20 questions, multiple-choice) to gauge both our students' background knowledge in the subject area and our students' mastery of skills associated with the build-test activity. The exam questions focused primarily on three key graduate attributes [2]:

1. 3.1.1 "A knowledge-base for engineering" (60% of the exam questions): these questions focused on specialized engineering knowledge appropriate to the build-test activity (e.g., photovoltaic effect) that was delivered primarily through lectures and textbook reading;
2. 3.1.3 "Investigation" (16% of the exam questions): these questions focused on students' analysis and interpretation of their experiments during the build-test activity, as well as their ability to synthesize information from the build-test activity to reach conclusions;
3. 3.1.5 "Use of engineering tools" (16% of the exam questions): these questions focused on students' ability to apply appropriate engineering tools to a range of build-test activities.

The exam questions primarily required students to recall information that they had read, discussed, or observed. For example, one of the Exam 3 questions relating to 3.1.1 "a knowledge base for engineering" was posed as follows:

> Solar ponds have solar-to-electricity conversion efficiencies as high as:
> (a) 2%
> (b) 7%
> (c) 14%
> (d) 22%

RESULTS

Figure 1 provides a summary of the results of the study: the exam and self-efficacy assessments are grouped in the three graduate attributes categories along the horizontal axis, and average exam scores and student self-efficacy are provided along the vertical axis. The average exam scores were calculated by summing the scores for all questions in each graduate attribute category across all four exams; the student self-efficacy results were based on the survey described in [1] where questions in each graduate attribute category are posed in the form of "how confident are you in your current ability to …", and students were required to rate their confidence on a five-interval scale ranging from 0% "no confidence" to 100% "total confidence".

It is promising to see that, as in our 2011 study [1], both the SSE and STU student cohorts reported increases in self-efficacy in each graduate attribute category. Given this PjBL course's focus on inquiry based learning, it is not surprising to see increases self-efficacy related to "knowledge base for engineering", "investigation", and "use of engineering tools", especially in the context of student efficacy research by Bandura [5] that shows that "the most effective way of developing a strong sense of efficacy is through mastery experience".

As can be seen in Figure 1, the self-efficacy results are consistent with the exam results when compared across the two cohorts: i.e., the SSE students report higher self-efficacy and receive higher exam scores for all three graduate attributes. These results also appear to be consistent with the peer assessment results reported by the authors in a companion paper at this conference [6]: i.e., SSE students received higher peer assessments than STU students from both cohorts.

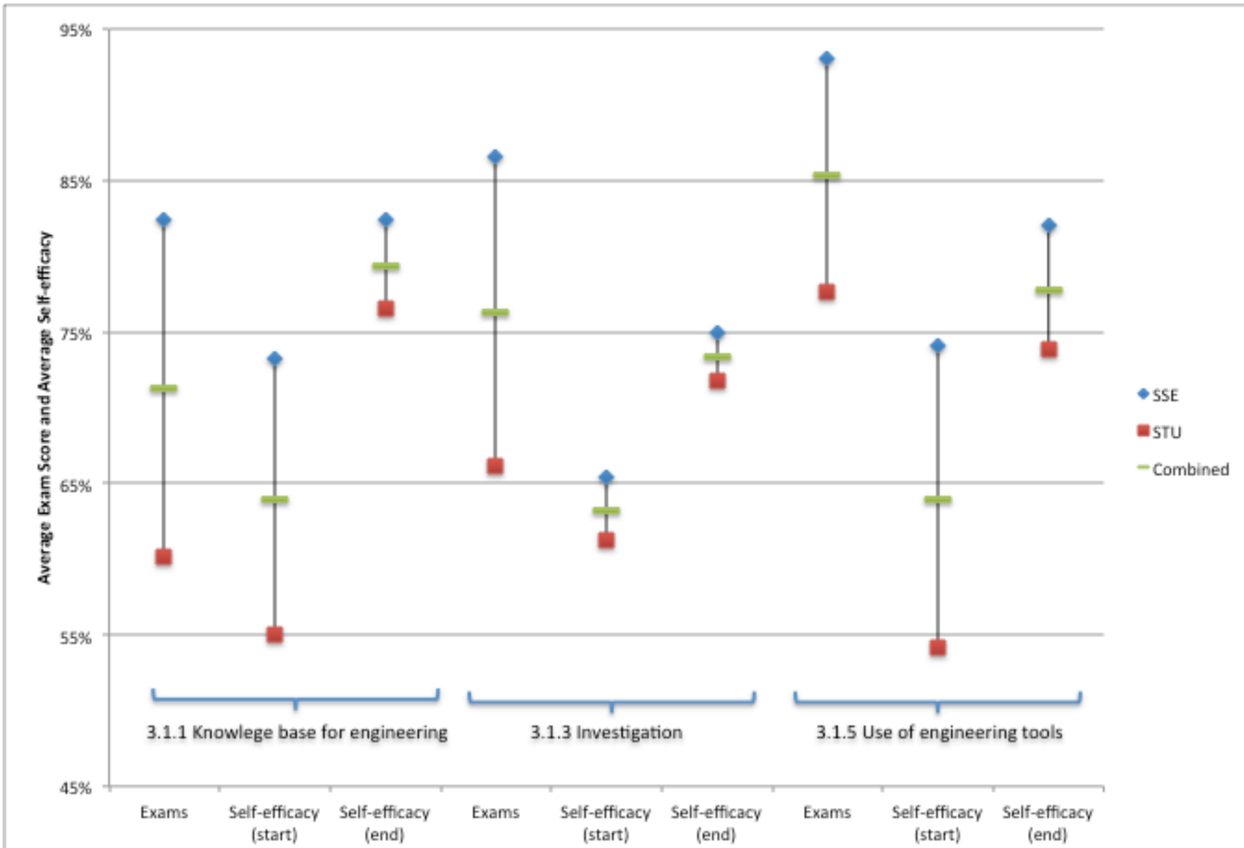

Figure 1. Comparing Student Self-efficacy with Examination Scores

The exam results and the self-efficacy results cannot be compared directly in Figure 1 given differences in the assessments: i.e., the exam results are based on percentage of correct responses to specific questions related to each of the graduate attributes; the self-efficacy results are based on students' perceived competency with respect to the overall graduate attribute. However, a comparison of these assessments provides interesting insights into students' perception of their competency in each graduate attributed (before and after the course) and their actual performance in these areas during the course.

In order to gain a better picture of the relationship between the more general self-efficacy assessments and the specific exam scores, each student's self-efficacy was compared with her/his exam performance for each of the three graduate attributes (i.e., 3.1.1, 3.1.3, 3.1.5). The exam scores for each graduate attribute were determined by averaging the results of all questions (i.e., across all four exams) corresponding to the specific graduate attribute. The correlation coefficient, *r*, between the self-efficacy results and the exam results was then calculated as summarized in Table 1.

As can be seen in Table 1, the correlation between exam and self-efficacy scores is relatively low. This likely a result of a mismatch between the format of the post-project exams and the self-efficacy survey: i.e., the exam questions were short, multiple-choice questions used to test students' basic comprehension of the related readings and the project, whereas the survey questions focused on broader skills that are expected to be attained by students by the time of graduation. When viewed in terms of Bloom's taxonomy [7], the exam questions required skills from the lower levels of the cognitive domain (i.e., knowledge, comprehension), while the self-efficacy survey questions attempted to address the full spectrum of graduate attributes (i.e., analysis, synthesis, evaluation).

Table 1. Correlation Between Self-efficacy and Exam Scores

Graduate Attribute	Number of Exam Qs	*r* at start of course	*r* at end of course
3.1.1 Knowledge base for eng.	49	0.361	0.200
3.1.3 Investigation	13	0.132	-0.075
3.1.5 Use of engineering tools	13	0.267	0.125

Although this exam format worked quite well for testing students' ability to recall basic engineering fundamentals and experimental observations from their course readings, in-class discussions, and laboratory sessions, it was not well suited to higher-level cognitive processes such as investigating, analyzing, interpreting, and synthesizing. This could explain why we see the highest correlation between exam and self-efficacy scores for 3.1.1 "a knowledge base for engineering" and "3.1.5 use of engineering tools" in Table 1, and also why 3.1.3 "investigation" ranks so poorly.

Figure 2 shows the individual student results for the graduate attribute with the highest correlation between post-project exam scores and student self-efficacy rankings (i.e., 3.1.1 "a knowledge base for engineering"). As would be expected, the graph shows a general upward trend: i.e., students who rate themselves low in terms of their knowledge base of engineering fundamentals at the start of the course score lower on the exams than students who ranked their knowledge base as high at the start of the course.

As noted previously, the two student cohorts (SSE and STU) have different perceptions of their own performance (i.e., Figure 1) and the performance of their peers (i.e., the results reported in [6]). In order to determine if this has an impact on the link between exam and self-efficacy scores, the individual cohort results for SSE and STU students are plotted in Figure 3 and Figure 4 respectively. Comparing these figures, one can see that the relatively high correlation for graduate attribute 3.1.1 is a result of correlation between exam and self-efficacy scores for the SSE students: the STU results in Figure 4 show very little correlation.

It should also be noted in Figure 2-4 that the exam scores are very high, and in a tight band (i.e., 70% to 100%) relative to the self-efficacy scores (i.e., 10% to 100%). This demonstrates the relative ease of the exam questions, and may also account for the low correlation between exam scores and self-efficacy results.

It is not clear from the survey and exam questions as to why there is such a difference between SSE and STU student perceptions of their abilities before the start of the course and their subsequent performance on exams. However, our results on peer assessment in these proceedings [6] may shed some light on this question. For example, the results of our peer assessment study show that peer assessment ratings are highly dependent on cultural and gender cohorts: this may explain the wide range of self-efficacy rankings in the STU cohort at the beginning of the course (i.e., Figure 4).

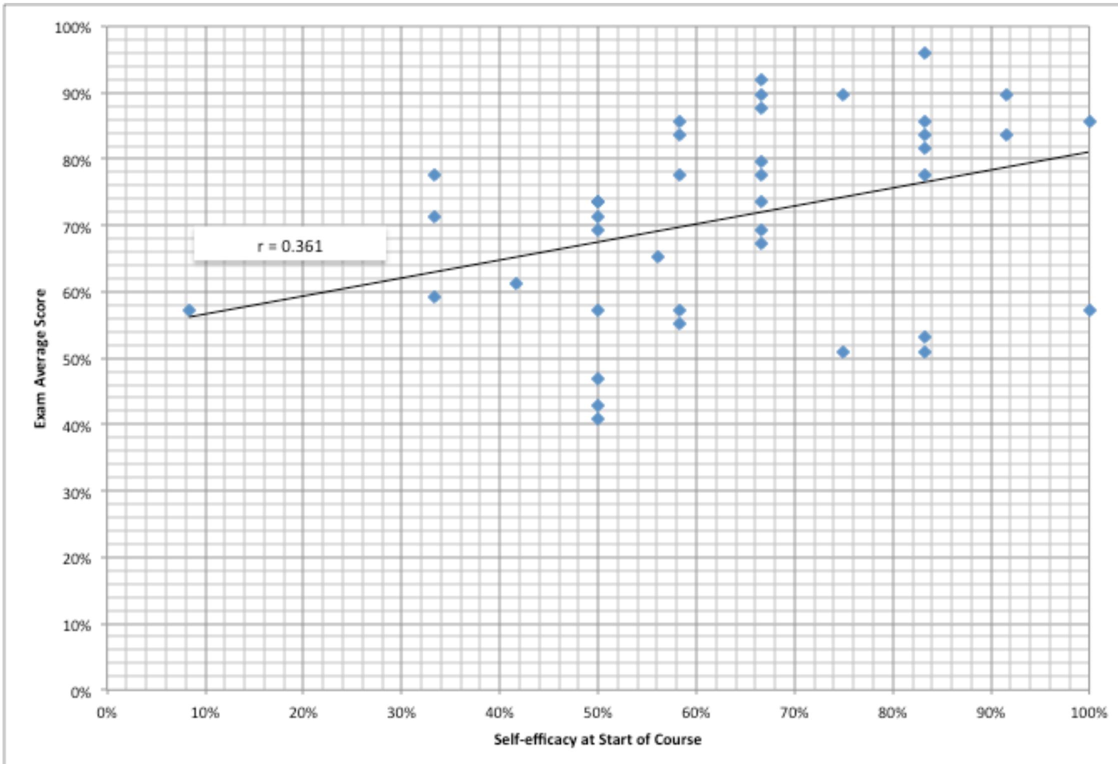

Figure 2. Correlation Between Starting Self-efficacy and Exam Scores for 3.1.1

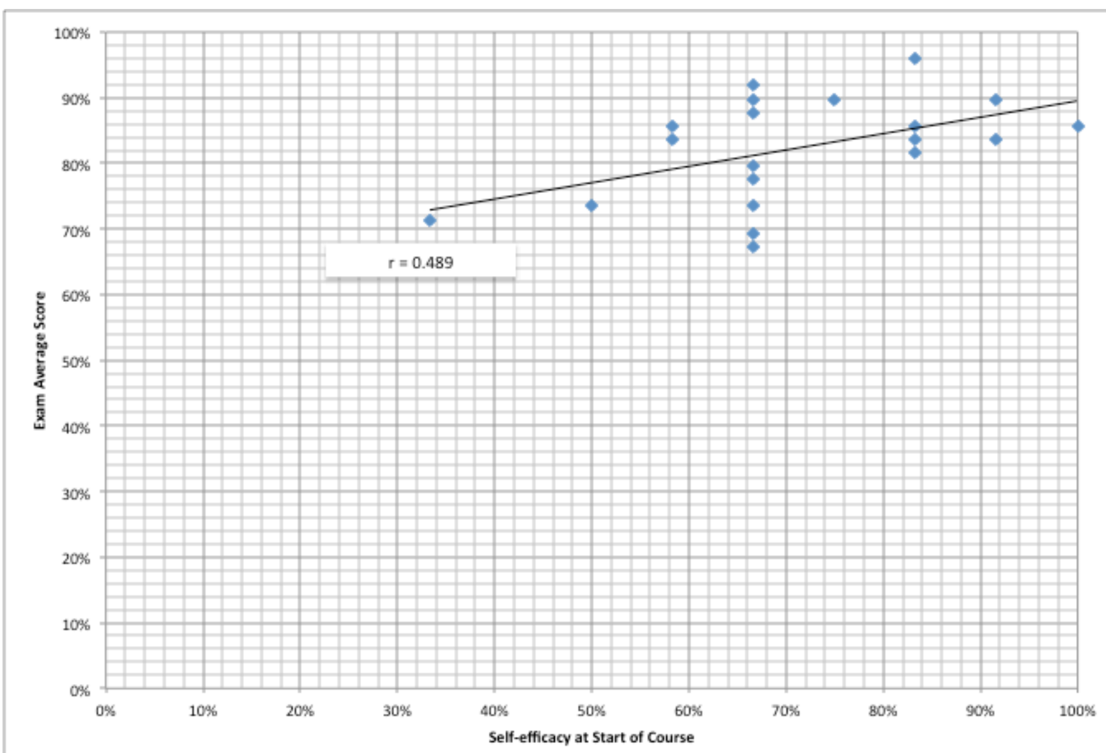

Figure 3. Correlation Between Starting Self-efficacy and Exam Scores for 3.1.1 (SSE Students)

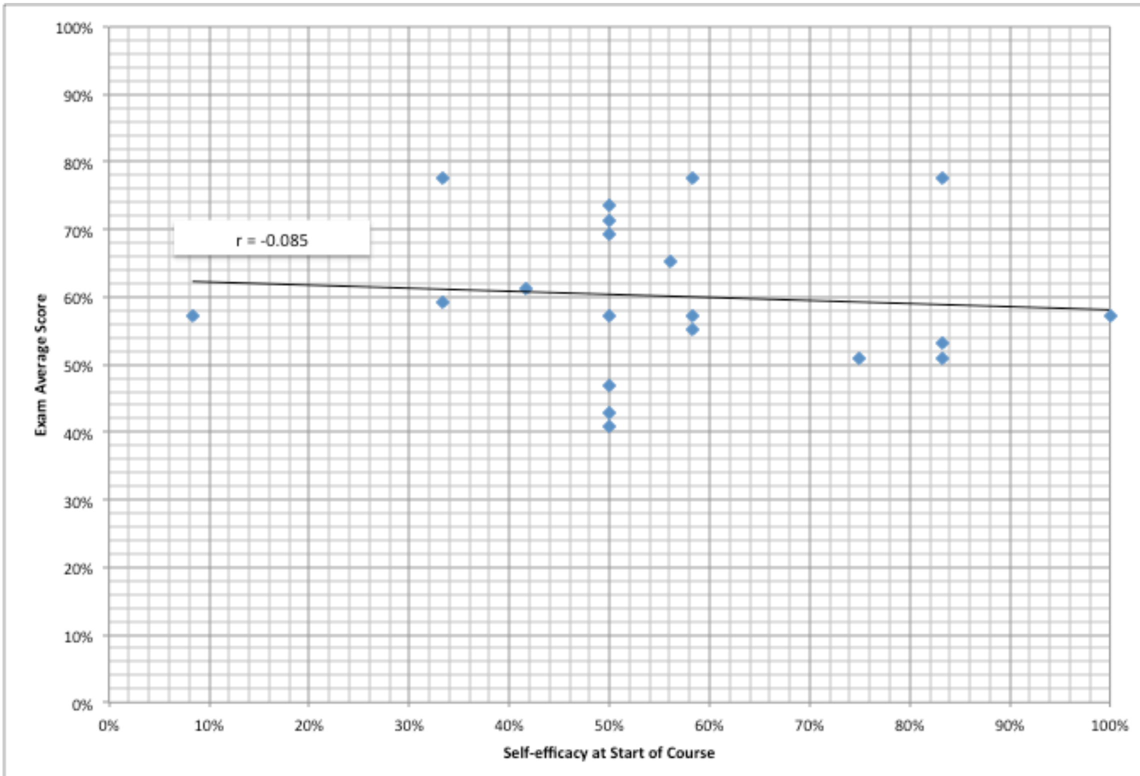

Figure 4. Correlation Between Starting Self-efficacy and Exam Scores for 3.1.1 (STU Students)

DISCUSSION

Although the correlation between self-efficacy and exam assessment data was less promising than we expected, the results of this study shed some light on general questions concerning graduate attributes assessment and PjBL teaching and learning. More specifically, the results show that it is important to design a stronger link between indirect and direct assessments (i.e., the self-efficacy survey questions and the post-project exam questions respectively).

From a graduate attributes assessment point of view, it is important that all forms of assessment are closely aligned so that individual assessments can be validated. In this case, the indirect assessments targeted a higher level of Bloom's cognitive domain than the direct assessments. In some cases (e.g., graduate attribute 3.1.1 "a knowledge base for engineering") the correlation between the results is, arguably, sufficient to provide a small degree of comfort with the assessments. However, if one is to use these results to assess student performance against established performance thresholds, better alignment is required between the various forms of assessment and the teaching and learning activities.

The results also point to opportunities with respect to project-based learning. Intuitively, PjBL appears to be a very good vehicle for developing higher-level cognitive skills such as the skills associated with graduate attribute 3.1.3 "investigation". The self-efficacy results in our previous study [1] as well as those shown in Figure 1 demonstrate that students do feel that the SSE/STU course increases their confidence in these attributes. However, more work is required on matching the direct, in-class assessments to the higher-level learning activities associate with project-based learning.

Finally, the cultural differences between the Canadian and Chinese cohorts appear to have had an impact the self-efficacy results as noted in the previous section. A cultural comparison is beyond the scope of this paper; however, based on anecdotal observations of the students involved in the two offerings of this course the large difference in self-efficacy results may be related to Chinese students rating themselves personally lower than Canadian students so as not to appear boastful (when in fact their abilities are actually similar).

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BIOGRAPHICAL INFORMATION

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