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A Case Study: How Collaborative PBL Affects Learning of Minority Students in Engineering Courses at Senior Level

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Abstract

This paper presents the current progress and preliminary findings of an NSF sponsored interdisciplinary research project that studies how collaborative PBL affects the self-efficacy of minority students in engineering. To achieve the project objectives, research activities are conducted collaboratively between an experienced engineering faculty and a learning scientist with substantial expertise on knowledge building communities and instructional system design. The first stage of the research is an empirical study performed in a pilot course (EE440) that employed CPBL to analyze its impact and develop a better understanding of the learning characteristic of minority students. This paper focuses on describing the research method and data analysis during the first stage. Preliminary findings identified critical factors in CPBL model that positively impacted the student learning process, and also indicated a few areas of improvement to enhance the effectiveness of the pedagogy. In the next research stage, the stage one study results will be applied to design a better instructional system based on the participatory design strategy.

Introduction

In recent years, many engineering educators incorporated project-based learning (PBL) to stimulate the students' interest via real-world design practice and positive impact on student learning outcomes were reported [1,2].This educational practice also prompted researchers to investigate the effectiveness of PBL in engineering classrooms [3,4]. The studies reported in literatures provided valuable insight on how to design better PBL experience for engineering students [5]. However, up to date research on this aspect is still not adequate to generate a comprehensive understanding of PBL in engineering context. In 2013, California State University Los Angeles received a RIGEE grant from NSF to conduct an interdisciplinary research to study the impact of collaborative project-based learning (CPBL) on the self-efficacy of traditionally underrepresented minority groups in electrical engineering courses. The project goals include: 1) Improve the understanding of the factors that affect the self-efficacy of minority student groups in Engineering; 2) Develop better ways to measure the impact of collaborative learning in the developmental stages of the student learning process in addition to the learning outcomes; 3) Design a more effective instructional system that integrates community inquiry to boost the self-efficacy of underrepresented minority students.

This paper presents our current progress on the RIGEE project, which is focused on answering the following research question:

"*How collaborative learning components in CPBL model affect the development of self-efficacy of minority students?* "

To answer the question, a descriptive case study framed as a single case with ten project teams as embedded cases was conducted in EE440 (a senior level computer networking course revised to integrate CPBL model) in Spring 2013. Embracing a mixed research methodology, both quantitative and qualitative data were collected through our study period. The data analysis was grounded in in both social cognitive and situated learning frameworks and produced interesting discovery on how individual learners' characteristic, the social aspects of collaborative learning, and the pedagogical components in *PBL* interacted to affect student learning. Particularly, *social interaction* was valued by students from all ethnical groups as the greatest motivating factor in CPBL. In this paper, the research method as well as the preliminary findings are described. In addition, this paper introduces a plan to redesign the pilot course (EE440) using a participatory design strategy based on the research results.

The paper is organized as follows. Section 2 presents the theoretical aspect and the research methodology used in our project. Section 3 provides an in-depth analysis of the pedagogical impact of CPBL model based on both qualitative and quantitative data. The course re-design plan is briefly described in Section 4, and Section 5 concludes the paper.

Theoretical Perspectives and Research Method

Self-efficacy has been identified as an important factor that influences the student learning process. Bandura [6] defined self-efficacy as "people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives." Notably, beliefs of personal efficacy are domain-specific and can be fostered through mastery experiences, vicarious learning (via modeling), and social persuasion.

To better understand how domain-specific self-efficacy might be fostered within the context of this study, a broader social constructivist perspective based on the theory of situated learning is considered. Broadly speaking, this perspective suggests learning as a demand driven, identity formation, and social act within a rich cultural and social context [7,8]. More specifically, proponents of situated learning theory maintain that a great deal of the actual practice of a profession is implicit in practice itself, and hence the classroom environment is "deliberately designed to de-skill" [9]. They do not agree with the separation between "knowing" and "doing"; instead, learning is described as a process of "enculturation," in which the learners are like apprentices learning to use domain-specific knowledge as tools as they develop an understanding of the rules and culture rooted in the community of practice. Thus, the learning process should resemble the ordinary practices of the culture, which usually involve collaboration, interaction, and social construction of knowledge. Herrington and Oliver's [10] critical elements of situated learning provide a useful framework to analyze the learning process, which include: (1) authentic contexts, (2) authentic activities, (3) access to expert performances and modeling, (4) multiple roles and perspectives, (5) collaborative construction of knowledge, (6) reflection, (7) articulation, and (8) coaching and scaffolding.

Our research is grounded in both social-cognitive and situated learning frameworks, since to answer the research question we need to look into a magnitude of input factors including the characteristics of individual learners, the social aspects in collaboration and the pedagogical components in PBL and investigate how they interact to affect student learning. To allow in-depth analysis of the impact of various components in CPBL on students with different cultural and ethnical backgrounds, descriptive case study is utilized as our primary research methodology, which is characterized by an embedded, single-case design to examine the students' self-efficacy beliefs collectively and individually. The data collection of this study followed the three principles suggested by Yin [11]: using multiple sources of evidence, creating a case study database, and establishing a chain of evidence. To develop converging lines of inquiry, our study utilized the following data sources: 1) pre and post surveys, 2) team collaboration surveys, 3) interviews, and 4) participant observation.

A pre-survey was administrated at the beginning of the quarter to measure specific knowledge and skills related to the course subjects, as well as students' general and engineering self-efficacy. The team collaboration survey was administrated electronically in the middle of the quarter. At the end of the quarter, students completed a post-survey which included the pre-survey items and additional items regarding their project experiences and their perceptions of the learning related to the critical elements of situated learning. Observation of class and team dynamics was carried out throughout the research period by the research assistant. In-depth interviews with the instructor, two teaching assistants, and a sample of students were conducted at the end of the quarter to supplement and verify data obtained from other methods.

All data sources were collected and organized into a case file for each project team. Data analysis involved the following procedures recommended by Creswell and Plano Clark [12]: preparing the data for analysis, exploring the data, analyzing the data, representing the data analysis, and interpreting the results. HyperRESEARCH was used for qualitative data analysis, which involved coding the data based on categories from the literature (e.g., Herrington and Oliver's critical elements of situated learning [10]) as well as codes that emerged from the data, assigning labels to codes, grouping codes into themes, and linking interrelated themes. Quantitative data analysis involved conducting a descriptive analysis of student ratings and examining the general trends of student responses. Various data sources allowed the researcher to triangulate observations and interpretations of findings. Member checking was employed in the form of ongoing discussions and clarifications among the researchers throughout the research period.

Data Collection and Analysis

This data were collected in the pilot course (EE440) in Spring 2013. The participants included 28 students and two teaching assistants who were also undergraduate students that participated in the same course in 2012. The student body contained 25% Hispanic, 25% Asian-American, 10.7% White American, 35% Foreign nationals, 4.3% other. The course has been revised to integrate CPBL-beyond-Classroom, a revised CPBL model to address the learning needs of under-prepared minority students at the senior level [13-15]. In EE440, five projects were developed and implemented, among which three were small scope projects that can be incorporated into lectures, one median scope (after-class), and one large scope term project that addressed open-ended design challenges. The three in-class projects were designed to build up the students' design skills progressively and allow them to gain sufficient knowledge and skills to tackle the ill-defined problem in the term project.

Evaluation of collected quantitative and qualitative data yielded interesting results regarding the relationship between CPBL pedagogy and the change of domain-specific efficacy. Here we will present our findings and discuss how they can lead to a better design of instructional strategies.

Quantitative Results

The analysis of pre-survey results revealed the following characteristics of individual learners: 1) all students (regardless of their ethnic groups) have high perceived general and engineering self-efficacy, and high expectancy values; 2) Hispanic students exhibited significantly lower domain-specific self-efficacy comparing to the others.

The comparison between the pre and post survey results indicated a general increase of students' efficacy in almost all learning outcomes (shown in Tables 1 and 2). However, the biggest growth occurred at the outcomes that were directly related to the project experience. This result is consistent with our multi-year assessment findings since 2010, which validated that CPBL does positively impact the development of domain-specific self-efficacy to accomplish design tasks. Furthermore, the analysis of student responses from different ethnic groups indicated that Hispanic students, although started with lower domain-specific self-efficacy, demonstrated the largest growth of self-efficacy through CPBL.

Table 1. Average Pre and Post survey results on knowledge outcomes: overall response vs. response from Hispanic students (*1 = None; 2= A little bit; 3=Somewhat familiar; 4= Familiar; 5= Expert; items with * are directly related to projects)*

Knowledge Outcome Index	All Students			Latino/Hispanic American		
	Pre	**Post**	**growth**	**Pre**	**Post**	**growth**
1. Knowledge of computer network design process	3.00	4.11	**1.11**	2.00	4.00	**2**
2. Knowledge of network simulation*	2.52	4.15	**1.63**	1.40	4.14	**2.74**
3. Knowledge of network performance analysis*	2.65	4.22	**1.57**	1.80	4.14	**2.34**
4. Knowledge of data communication model	2.96	4.07	**1.11**	2.00	3.86	**1.86**
5. Knowledge of layered network architecture (OSI and TCP/IP model)	2.83	4.26	**1.43**	1.80	3.86	**2.06**
6. Knowledge of various data encoding technologies (NRI, Manchester coding)	1.83	4.63	**2.8**	1.20	4.14	**2.94**
7. Knowledge of network topology (bus, star, etc.) *	2.83	4.33	**1.5**	2.00	4.14	**2.14**
8. Knowledge of ARQ*	2.17	4.04	**1.87**	1.20	3.71	**2.51**
9. Knowledge of Ethernet	3.17	4.22	**1.05**	2.20	3.86	**1.66**
10. Knowledge of how to build and extent a Local Area Network using bridge*	2.43	4.31	**1.88**	2.00	4.29	**2.29**
11. Knowledge of CSMA/CD*	2.30	4.07	**1.77**	1.00	3.86	**2.86**

Table 2. Average Pre and Post survey results on students' efficacy on content-specific skills: overall response vs. response from Hispanic students (*1 = Strongly Disagree; 2 = Disagree; 3 = Somewhat Agree; 4 = Agree; 5 = Strongly Agree; items with * are directly related to projects*).

Content-specific Efficacy Index	All Students			Latino/Hispanic American		
	Pre	**Post**	**growth**	**Pre (5)**	**Post (7)**	**growth**
1. I am confident in my computer skills	3.96	4.59	**0.63**	3.60	4.57	**0.97**
2. I am confident in my communication skills	3.83	4.26	**0.43**	3.60	4.14	**0.54**

3. I have good Math skills	4.09	4.52	**0.43**	4.20	4.43	**0.23**
4. I am confident in my ability to identify user needs and define specifications to design a network system.	3.13	4.15	**1.02**	3.20	4.00	**0.8**
5. I am confident that I can design a network scenario in OPNET*	2.78	4.37	**1.59**	2.20	4.43	**2.23**
6. I am confident that I can analyze the network performance using simulations*	3.04	4.48	**1.44**	2.20	4.57	**2.37**
7. I am confident that I can optimize my network design based on realistic constraints using OPNET*	2.65	4.12	**1.47**	2.00	4.33	**2.33**
8. I am confident in my ability to use OPNET to explore and learn new network protocols*	2.74	4.26	**1.52**	1.80	4.43	**2.63**
9. I am confident that someone like me can succeed in an engineering career.	4.48	4.74	**0.26**	3.60	4.57	**0.97**
10. I think that engineering is the best (most fitting) major for me.	4.65	4.59	**-0.06**	3.60	4.14	**0.54**
11. I feel at home when working with other engineers.	4.22	4.30	**0.08**	4.20	4.43	**0.23**

To better visualize how different student groups responded to CPBL, group difference is defined in equation 1 to represent the difference in reported growth in domain-specific efficacy between Latino students and the class average:

$$\textit{Difference} = \textit{Reported growth by Latino students} - \textit{Average growth in class.} \qquad (1)$$

Figures 1 and 2 compares the group difference of CPBL related knowledge and skills against the non-CPBL related ones. It is obvious to see that overall CPBL-related efficacy was associated with larger difference; In particular, for skill specific efficacy directly related to CPBL, Latino students reported much bigger growth comparing to other ethnic groups. This made us believe that Latino students benefited more from CPBL and this finding agrees with the observation made by Halyo and Le (2011) that "most minority students are visual learners", and thus they are more successfully in an interactive and hands-on learning environment.

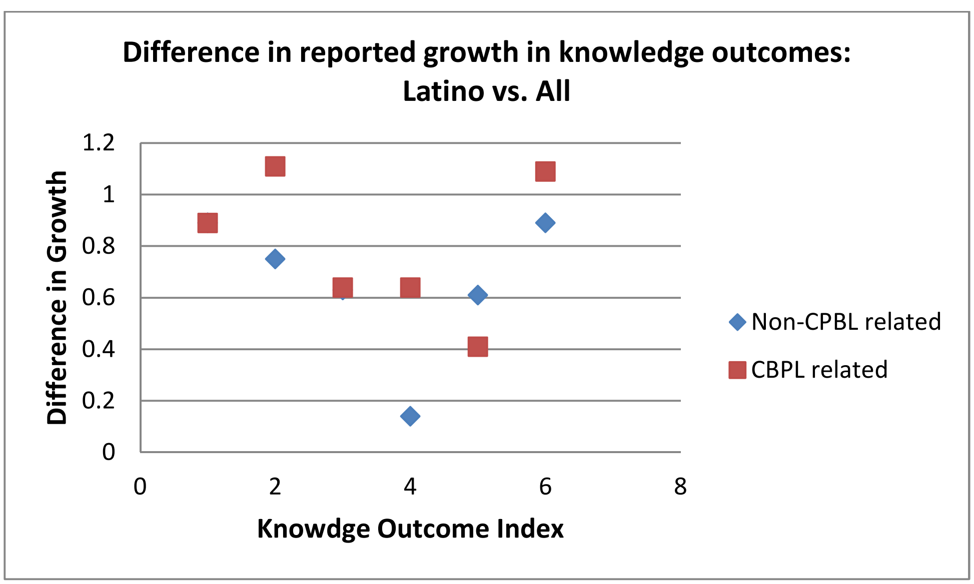

Figure 1. Group difference in reported growth in knowledge specific efficacy (Latino vs. All)

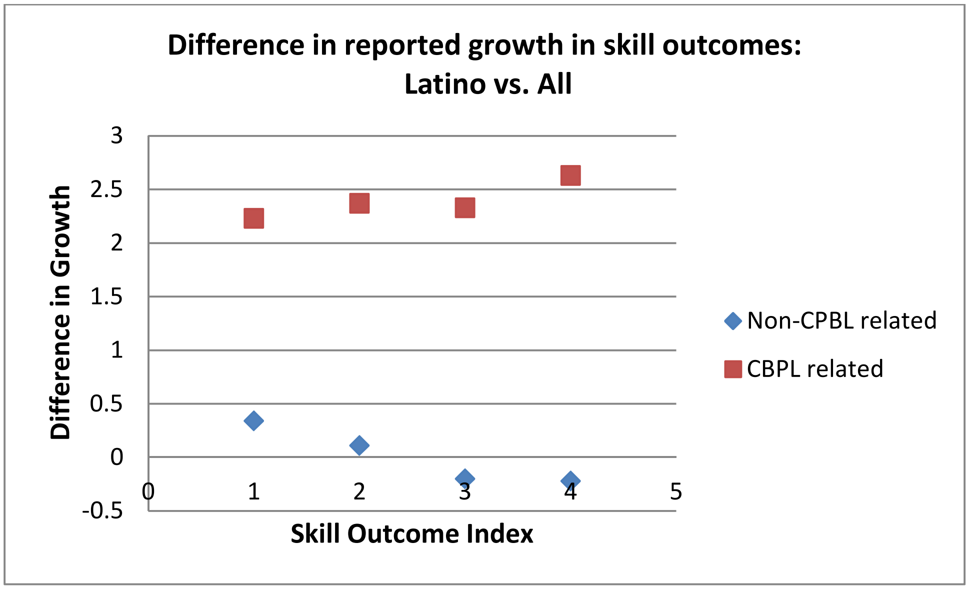

Figure 2. Group difference in reported growth in skill specific efficacy (Latino vs. All)

Post survey also indicated that among the critical elements of situated learning, the following are valued highest: *peer-collaboration*, *multiple roles/perspectives*, and *coaching*. In particular, the social construction of knowledge (collaboration, knowledge sharing, discussion) is best recognized by students from all ethnic groups. This finding is reinforced by the results from the team collaboration survey.

Qualitative Results

Qualitative results revealed that students developed **greater level of self-efficacy related to the course subject, engineering design, and people skills** through their project experiences. Table 3 categorized the qualitative findings derived from interviews and open-ended questions in surveys. Overall, students indicated a high level of interest and engagement, and they reported learning multiple skills such as research, communication, design, technology (OPNET), and people skills. The term project was most liked by the students due to its open-ended nature and the social/constructive elements of project design helped the students to “boost their confidence” as future engineers.

Table 3. Categories of qualitative findings in Stage One research

Category	Summary of findings
Expectance Value	Overall students expressed fairly high expectancy value and reported that their actual performance matched their expectation.
Self-efficacy	• Overall, students reported that their confidence in their engineering career was *not* significantly impacted by the project experience. • Students reported a greater level of self-efficacy related to the course subject, engineering design, and people skills.
Student Engagement	• High level of student engagement was reported. The main contributing factors included: Interactive lecturing; peer collaboration; **social** and **constructive** process of design; in-time support & online resources.

	• Also, many students found the project experience enjoyable due to the real world application of practical skills that directly benefit their future career.
Learning Process	• Students responded positively to "learn-by-doing" feature in CPBL, and reported that they liked the "structured design" of the class projects that prepared them progressively with adequate knowledge and skills to work on real-world design challenge. • Other positive features in the learning process include: 1) learn from multiple perspectives (during team work); 2) the constructive and social learning process that actively involves students in "building from prior knowledge", "tying everything together", "understanding different scenarios/perspectives", "looking deeper", and "making sense".
Social Context in PBL	Although most students enjoyed working in their teams and reported that social construction of knowledge was very valuable in their learning, many reported working in a team presented challenges. Both positive and negative team dynamics were reported, including: • *Positive group dynamics*: common goals; group collaboration; friendly relationship; opportunity to learn from the strengths and weaknesses of other people. • *Negative group dynamics*: problems in communication; disagreement among team members; scheduling; uneven distribution of workload.
Project Design	• Overall, the students reported positive feedback regarding the project design (and contents). Many students thought that the project provided good learning experience and allowed them to see the difference between theory and realistic practice. The term project was most liked due to its open-ended nature. • The perceived difficulty related to the projects include: 1) answering conceptual questions, 2) analyzing the results, 3) interpreting the results, and 4) working with the OPNET software.

While teamwork/social interaction appeared to foster student motivation and a sense of responsibility for some group members to go "above and beyond" project requirements, it also created certain challenges such as scheduling conflicts and disagreement among group members. In particular, time constraint was recurrently reported as one of the most challenging aspects of the project experience.

An interesting finding from the qualitative results is that factors like gender, ethnics, and Social Economical Status (SES) seem to have little influence on the students' project experience. Instead, group dynamics played a more significant role in their learning process.

Course Redesign Process

The findings from the data analysis identified several key factors that positively impacted the students' motivation and enjoyment in CPBL, as well as potential challenges. In the next stage of our research project, these findings will be leveraged to design more effective PBL learning experience with compelling group collaboration for engineering students. This section briefly describes the principle and plan to redesign EE440 using participatory approach.

The re-design process starts with a careful examination of the theory of situated learning and its connection to our CPBL model. By situating the learning environment, we are creating a "practice field" [16] with the kinds of problems and practices relevant to what students will encounter outside of school. By mapping out the various learning components in our CPBL model to Barb and Duffy's design principles [16], we have found many parallels in our approach as well as areas that could be enhanced. These principles include: (1) doing domain-related practices, (2) ownership of the inquiry, (3) coaching and modeling of thinking skills, (4) opportunity for reflection, (5) dilemmas are ill-structured, (6) support the learner rather than simplify the dilemma, (7) work is collaborative and social, and (8) the learning context is motivating.

To further improve the impact of CBPL on student learning, our redesign strategies incorporate pedagogical methods based on cognitive apprenticeship and its four building blocks [17]: content, method, sequence, and sociology. Participatory approach is used in the course redesign process. The principle of participatory design is to involve the end users (which are the students in our case) in every stage of the design process. So far, three student co-designers with different ethnical and cultural backgrounds have been identified. All of them are from previous EE440 class offered in Spring 2013 and worked in different project teams. Hence the selected student co-designers can well represent the students' perspectives in the course re-design process. Figure 3 depicts the major steps in our planned course re-design process and indicates how faculty and students' perceptions are incorporated in each design step.

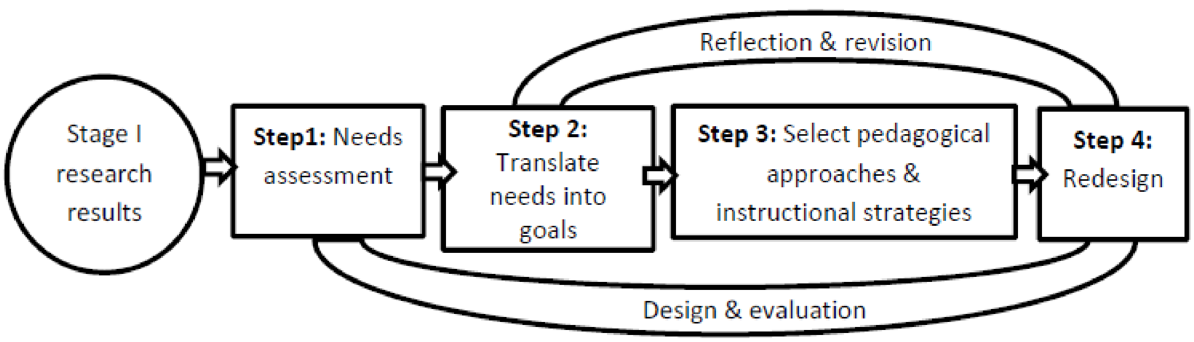

Figure 3. Process of course re-design using participatory design principle.

Conclusions and Future Work

Our current research highlighted several critical factors that positively impacted the students' motivation and enjoyment in CPBL, which include group learning, the nature of design project, and various resources and supports provided to the students. CPBL enabled the students to actively explore and experiment with different design scenarios, and helped to promote their intrinsic desire to understand the subjects and increase their domain-specific self-efficacy. The findings also identified potential challenges including how to provide sustainable motivation in PBL process, how to enhance team collaboration and improve time management. Based on the research results, we have initiated the course redesign process using participatory design principle. The future work will be focused on the course redesign as well as close evaluation of the pedagogical impact of CPBL in the redesigned instructional framework.

Acknowledgment

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