



## **Designing Effective Project-based Learning Experience using Participatory Design Approach**

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## Abstract

This paper presents the progress and findings of the second stage of an NSF sponsored interdisciplinary research project that aims at developing guidelines of effective instructional design using collaborative PBL (CPBL) to boost the self-efficacy of minority students in engineering. To achieve the above goal, an exploratory case study was conducted, where we first utilized an innovative instructional design strategy called Participatory Design Approach to improve the curricular structure and CPBL model in a pilot course (EE440), and then analyzed the students' responses to the revised pedagogical model via mixed methods research based on both quantitative and qualitative data analysis. While this paper describes the complete course re-design process using participatory approach as well as the resulted pedagogical changes in the revised CPBL model, the focus is to share the research findings on the impact of course redesign on student learning. During the implementation of the revised CPBL in the pilot course, significant improvements in student participation and project performance were observed. Detailed data analysis reveals the underlying factors that led to the change of students' learning behaviors. Our research findings indicate that well designed PBL model helps to promote deeper learning.

## Introduction

With the wide adoption of project-based learning (PBL) in engineering programs, many research studies were conducted to evaluate its effectiveness in engineering education [1-3]. Some research results showed that PBL is not only effective to deepen students' understanding of engineering principles, but also helps them to develop abilities to apply those principles in engineering design practices [3]. In the meantime, many engineering educators have shared successful stories of using PBL to improve student learning in their practices [4-8]. Evidentially, PBL has shown a strong promise as an effective teaching pedagogy in engineering education. Naturally, a follow-up question is *how to develop an effective instructional system using PBL for engineering students*. Up to date, research on this area is very limited. Consequently, many instructors have struggled to find their own implementation strategies via "trial and error", and some eventually gave up due to frustration, student resistance, as well as workload issues.

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 student learning with the goal to explore effective instructional design method to increase the success of engineering students, in particular the students from underrepresented minority groups. The research consists of two major stages. The first stage is an empirical study conducted in EE440, a pilot electrical engineering course that was revised to employ CPBL, to analyze the pedagogical impact of CPBL and develop a better understanding of the learning characteristics of minority students. The first stage work was conducted in year 2013 to 2014, and the findings were reported in our previous ASEE publication [9]. The second stage of research is to leverage the findings from stage one study to enhance the design of the

instructional system that incorporates CPBL in order to produce a more engaging learning experience and increase student success.

This paper presents the progress and findings of research conducted in stage two, including the course redesign process, the primary pedagogical changes in revised CPBL, and the consequent impact on student learning. The course re-design was conducted using an innovative approach called *participatory design strategy*. 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. Guided by the theory of situated learning, the faculty and student co-designers worked together to re-examine the CPBL model and revise the pedagogy based on cognitive apprenticeship and its four building blocks: content, *method*, *sequence*, and *sociology*. The revised CPBL allowed students to define their own projects and provided more opportunities for students to reflect on their own learning strategies and performance. The redesigned course was offered in Spring 2014, and significant improvement in term project performance was observed. To analyze the impact of the pedagogical revision, a mixed methods research was used to collect both quantitative and qualitative data including pre- and post- survey, informal and formal interviews, and participant observation. The interview was conducted multiple times throughout the quarter to track the change of student motivation and participation in the class projects. The paper includes detailed data analysis to reveal how students with different academic and cultural backgrounds responded to the revised CPBL and discusses why these changes helped to promote deep learning in PBL.

## **Course Redesign using Participatory Design Approach**

### *Why Participatory Design Approach*

The move from the traditional instructional design (ID) approaches to learner-centered design practices reflects recent philosophical shift from behaviorism to constructivism in the field of learning sciences [10]. As an innovative instructional design approach, participation design (PD) reflects the pluralistic, post-modern philosophy by making the design process more democratic for various stakeholders involved. The basic idea is that target learners of a system should play an important role in designing the system. According to Carroll, Chin, Rosson, and Neale [11], participatory design approach can be described as a process of mutual learning in which co-designers are empowered to make real and substantial design decisions. Research in this area has addressed the cooperative process of design and development of expertise, while including students in pedagogical planning processes. In particular, studies have found that students are able to play an important role as co-designers and the end products are better designed to meet their personal needs and expectations [12].

In our research, Participatory Design Approach was selected to redesign our instructional system using CPBL, since we believe that by engaging the target learners in the design process, we can shape a curriculum that better fits the learning characteristics of our students, and to promote “locality, diversity, involvement, and collaboration” [12]. In addition, since Participatory Design Approach has not been adequately exploited and studied in the educational research area, our work will contribute to the existing knowledge base, and shed some light on how to use it effectively to make the learning process more engaging and productive.

### Course Redesign Process and Product

The course redesign process using Participatory Design Approach is somewhat similar to the engineering design process. The first step in engineering design is user requirement analysis, where all stakeholders work together to define the design goals. Similarly, to design an instructional system to meet the students' needs, the instructor and student co-designers conduct a needs assessment first to analyze the problems of the existing instructional system, and subsequently transferred the identified needs to the goals of course re-design. Since the student co-designers play a significant role in shaping the curriculum, it is important to select students that can well represent the diverse cultural and ethnic backgrounds of the student body whose inputs shall reflect different team experiences. After the goals are specified, the instructor and the students again collaborate to prototype the instructional system and proposed ideas to revise the CPBL model. After iterative discussion, revision and refining, the curriculum is finalized along with the improved teaching pedagogy. The detailed course redesign process has been presented in our previous publication [13], here we would like to highlight the pedagogical changes in the revised CPBL, since this paper focuses on analyzing their impact on student learning.

First of all, the pedagogical methods of CPBL were enhanced to include all critical elements in situated learning framework (*Authentic Context, Expert Modeling, Coaching and Scaffolding, Reflection, Exploration, and Articulation*) [14, 15]. In our past implementation, the design of CPBL was focused on the project content, hands-on practice as well as scaffolding to help students succeed. While all of these are important components, inadequate opportunity was provided for students to reflect and articulate their learning. In the revised CPBL, student teams were required to develop design journals to periodically reflect on what they had learned, their team work experience, and their design progress. In addition, group discussion became a critical part of each project. In the term project, students also needed to create a flyer to promote their design product. The enhanced reflection/articulation helped to complete the learning cycle in CPBL and ensure the achievement of learning outcomes.

Using the revised CPBL mode, the instructor and student co-designers revised the term project structure for EE440 as shown in Figure 1. As an open-ended design challenge, the original term project required student teams to define the project goal, propose technical solutions, and evaluate their performance using simulation tools. Each team also submitted a report to describe the results, which are verified network solutions for a virtual target business. The revised term project kept the same primary structure, but added several new components. First, student teams needed to conduct research to investigate what are the desirable features of a network solution for a real business and used their research findings to define their project goals. This step increased the student motivation, since they could select to do the design for their "dream companies" which gave them a sense of ownership in the design process. Furthermore, the reflection and articulation components were enhanced via design journals and the poster presentation. A design contest was hosted based on their developed posters where all students, the instructor and invited engineers served as judges. The revised term project was very successful and significant performance increase was observed.

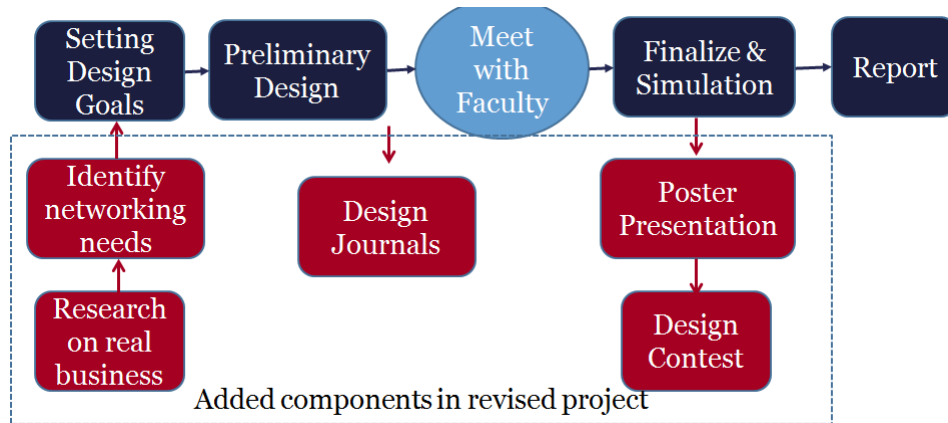


Figure 1. Difference in term project structure before and after the course redesign.

Another major change in the revised curriculum was the explicit instruction on learning strategies. When we investigated students’ learning characteristics during stage one research, we found that many students do not possess adequate learning strategies even in a senior-level engineering course. This observation is consistent with findings reported by other colleagues [16]. The revised instructional system offered resources and tools to help students learn how to learn. Figure 2 illustrates the website we developed for this purpose. Students could identify their strength and weakness through the pretests, and develop a better understanding of various learning strategies, such as time management and team skills through interactive activities. In addition, they could get advices from their peers (appeared as “student avatars”) who attended the same course in the previous years. This change helped to address the timing problems and workload issues that were encountered by many students who had to work for more than 20 hours per week in addition to their college study.

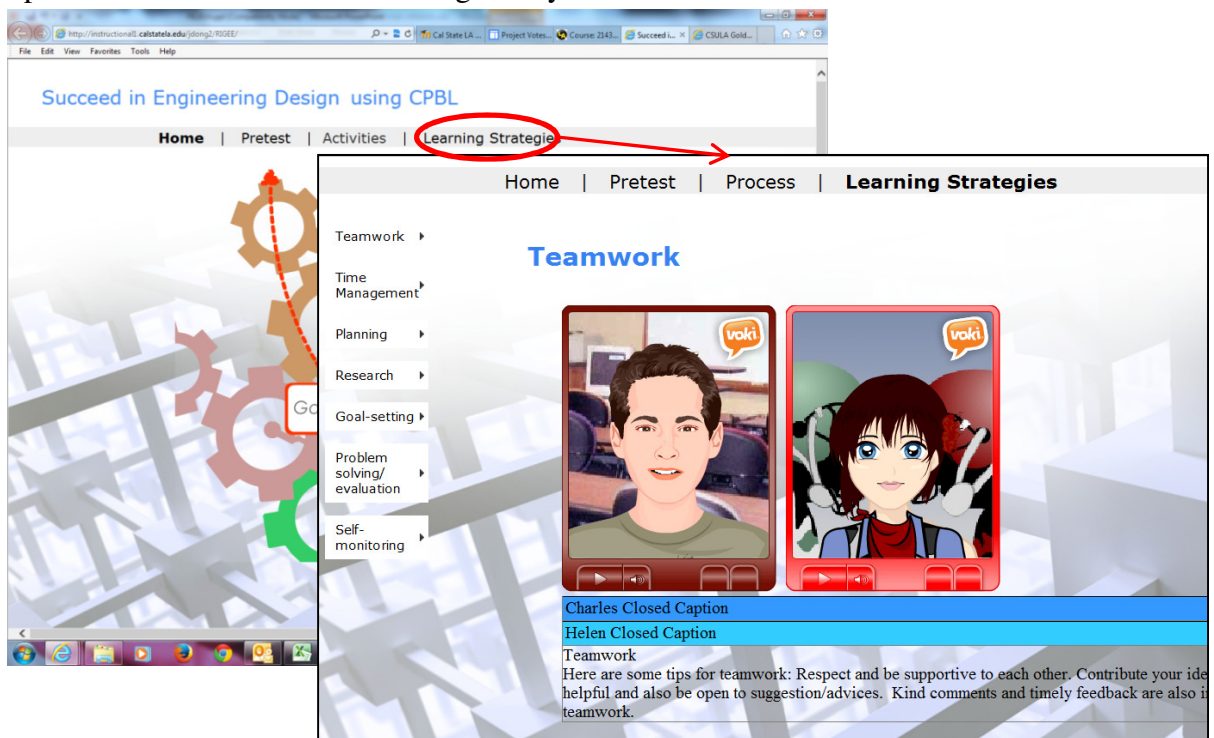


Figure 2. Online Tools to Enhance Students’ Learning Strategies.

## Impact of Course Re-design on Student Learning

The redesigned course using Participatory Approach turned out to be very successful in promoting deep learning. To probe how the revised instructional system affected student learning, a mixed methods research was conducted to answer the following guiding question: “How does the re-designed CPBL course affect student engagement and agency across different student groups?” Table 1 lists the data collection tools used in the research of pilot course (EE440, Spring 2014). Similar to the previous year, 30 students enrolled in the course and 10 teams were formed to work on a series of projects. This section presents both the observed students’ performance and the findings from the quantitative and qualitative analysis.

**Table 1. Data collection instruments used in the mixed methods study in EE440, Spring 2014.**

<b>Sources of Data</b>			
<b>Unit/Level of Analysis</b>	<b>Class</b>	<b>Design Teams</b>	<b>Individuals</b>
<b>Knowledge and skill indicators</b>	Pre- and post- surveys Formal and Informal interviews (sample students) Observation notes (professor and RA) Professor and TA reflections Exams (knowledge) Projects (skills)	Pre- and post- surveys Formal and Informal interviews (sample students) Observation notes (professor and RA) Design journals Moodle participation statistics Professor and TA reflections Term projects and posters Grades	Formal and Informal interviews (sample students) Observation notes (professor and RA) Design journals Moodle participation statistics Professor and TA reflections Term projects and posters Grades
<b>Efficacy and Situated Learning (cognitive apprenticeship) indicators</b>	Pre- and post- surveys Formal and Informal interviews (sample students) Observation notes (professor and RA) Design journals Professor and TA reflections	Pre- and post- surveys Formal and Informal interviews (sample students) Observation notes (professor and RA) Design journals Professor and TA reflections	Formal and Informal interviews (sample students) Observation notes (professor and RA) Design journals Professor and TA reflections
<b>Engagement (deep vs. surface learning) indicators</b>	Pre- and post- surveys Formal and Informal interviews (sample students) Observation notes (professor and RA) Design journals Moodle participation statistics Professor and TA reflections	Team profiles (Google site) Pre- and post- surveys Formal and Informal interviews (sample students) Observation notes (professor and RA) Design journals Moodle participation statistics Professor and TA reflections	Formal and Informal interviews (sample students) Observation notes (professor and RA) Design journals Moodle participation statistics Professor and TA reflections

### Observed Changes in Student Participation and Team Performance

To monitor student participation in the redesigned course, the research assistant (RA) for the project who is a MS student from the College of Education regularly sat in both the lecture and project sessions to observe student learning and classroom dynamics. Increased in-class participation was reported by the RA, teaching assistant (TA), and the Professor, and this observation is verified by the Moodle participation statistics. Figure 3 compares the numbers of online learning activities on Moodle Course site before and after the course redesign. The

activities consist of “view” and “post”, which indicate the frequency of student access to class notes, tutorials, handouts (View) and their participation in online forum, discussions, and voting activities (Post). In both years, View dominated the online activities (about 90%), but we can clearly see that the amount of online learning activities almost *doubled* in the redesigned course.

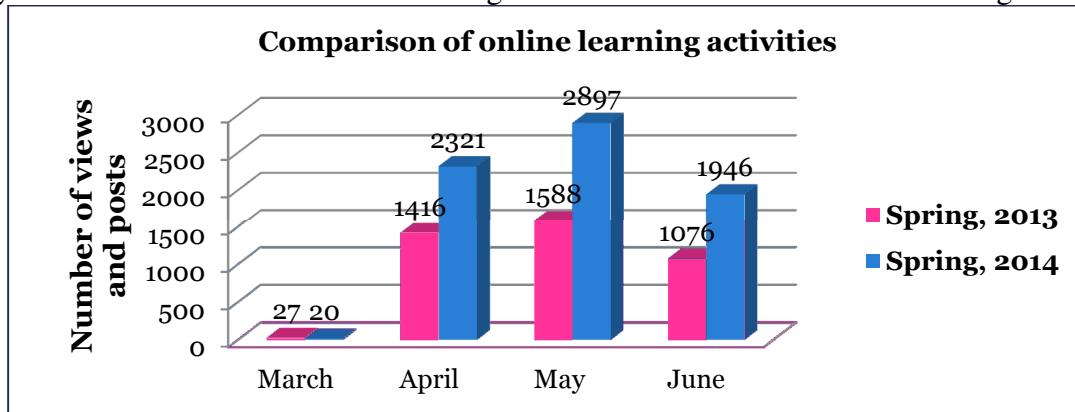


Figure 3. Comparison of students’ online learning activities (numbers of Views and Posts) on Moodle course site between 2013 (before redesign) and 2014 course (after redesign).

In addition, the average performance of student team project was also improved. In the previous year, although many students were initially motivated by the project ideas, most teams eventually ended up with very basic design products that barely met the minimum requirements. In the redesigned course, almost all student teams stayed strongly motivated throughout the design process and many teams went above and beyond the basic requirements to incorporate advanced features in their design product, e.g. reliability, security and/or mobility. Figure 4 shows an example of improved project performance before and after the course redesign.

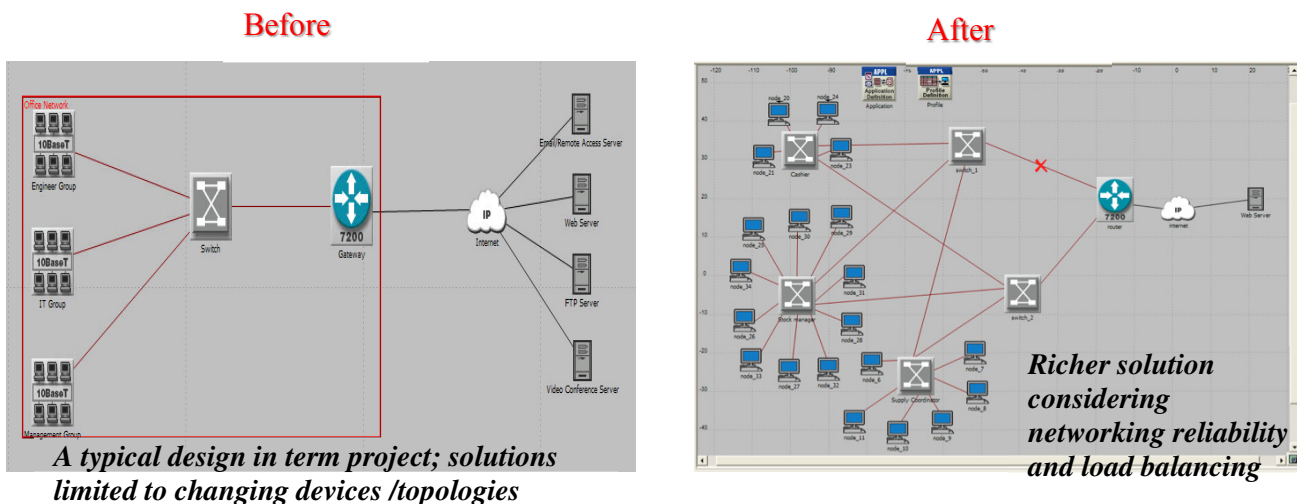


Figure 4. Comparison of students’ performance on term project: the left-hand side shows a typical networking design used by most student teams in 2013 course, which just met the most basic project requirements; the right-hand side is a snapshot of one team’s work in 2014, which not only met the basic requirements, but also considered how to make the network reliable even when link error occurred.

Quantitative Results

While it is very encouraging to see the effectiveness of the course redesign, it is more important to understand “why it worked” in order to develop effective instructional design guidelines, As shown in Table 1, pre- and post- surveys were used in our study to measure the change of students’ knowledge/skills efficacy. Comparison study using pre- and post- survey results indicated:

- 1) Students reported significant increase of efficacy in almost all knowledge and skills outcomes and the biggest growth occurred at the outcomes that were directly related to the project experience.
- 2) Latino students reported larger growth in all of the knowledge outcomes, as well as larger growth in 3 out of 4 skill outcomes related to CPBL compared to the class average, as shown in Tables 2 and 3.

**Table 2. Average 2014 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	2.40	4.08	<b>1.68</b>	1.67	4.00	<b>2.33</b>
2. Knowledge of network simulation*	2.20	4.13	<b>1.93</b>	1.50	4.20	<b>2.70</b>
3. Knowledge of network performance analysis*	2.13	4.04	<b>1.91</b>	1.67	4.00	<b>2.33</b>
4. Knowledge of data communication model	2.40	4.04	<b>1.64</b>	1.83	4.00	<b>2.17</b>
5. Knowledge of layered network architecture (OSI and TCP/IP model)	2.50	4.00	<b>1.50</b>	1.33	4.20	<b>2.87</b>
6. Knowledge of various data encoding technologies (NRI, Manchester coding)	1.87	4.37	<b>2.50</b>	1.33	4.40	<b>3.07</b>
7. Knowledge of network topology *	2.20	4.21	<b>2.01</b>	1.83	4.40	<b>2.57</b>
8. Knowledge of ARQ*	1.56	3.71	<b>2.15</b>	1.17	4.00	<b>2.83</b>
9. Knowledge of Ethernet	2.59	4.08	<b>1.49</b>	2.00	4.20	<b>2.20</b>
10. Knowledge of how to build and extent a Local Area Network using bridge*	2.13	4.09	<b>1.96</b>	1.50	4.00	<b>2.50</b>
11. Knowledge of CSMA/CD*	2.07	3.67	<b>1.60</b>	1.33	4.00	<b>2.67</b>
12. Knowledge of OPNET Software	1.93	3.96	<b>2.03</b>	1.17	3.80	<b>2.63</b>

**Table 3. Average 2014 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).**

Skill Efficacy Index	All Students			Latino/Hispanic American		
	Pre	Post	growth	Pre	Post	growth
1. I am confident that I can design a network scenario in OPNET*	3.23	4.44	<b>1.21</b>	3.00	4.00	<b>1.00</b>



2. I am confident that I can analyze the network performance using simulations*	3.23	4.44	<b>1.21</b>	2.67	4.00	<b>1.33</b>
3. I am confident that I can optimize my network design based on realistic constraints using OPNET*	3.30	4.24	<b>0.94</b>	2.67	3.80	<b>1.13</b>
4. I am confident in my ability to use OPNET to explore and learn new network protocols*	3.50	4.16	<b>0.66</b>	2.67	3.80	<b>1.13</b>

It is worthwhile to mention that the findings in Tables 2 and 3 are consistent with what we found last year. In addition to the knowledge/skill indicators, the pre- and post- surveys also evaluated students' intrinsic goal orientation, general self-efficacy, and the use of metacognition strategies. The dependent t-test revealed a statistically significant change on the students' metacognition between pretest and posttest with respect to this item: "When studying for this class, I often reflect upon what I have done and what I can do to improve." This suggests the redesigned course was successful in increasing students' metacognitive awareness of their own learning process. Finally, students reported highly positive experiences with the situated learning pedagogical model in the post survey. Along with qualitative evidence, we believe that the CPBL in combination with situated cognition and deep learning approaches constructed a more effective learning environment for our students from minority groups.

### Qualitative Results

The data sources for qualitative analysis include: 1) open-ended questions in post-survey; 2) informal and formal student interview; 3) student Design Journal; and 4) faculty/TA reflections. The richness of data sources allowed us to triangulate observations and interpretations of findings. While the qualitative results provide a comprehensive analysis of the redesigned instructional system, this subsection will focus on analyzing its impact on student engagement, efficacy, and learning style.

#### **1) Student Engagement in Revised CPBL**

To understand how the revised CPBL impacted the nature of student engagement, we looked into specific task components as shown in the table below. Among the task list, component 1 is enhanced and components 2 and 7 are newly introduced in the revised CPBL. Consistent with the quantitative findings obtained from the post-survey, students reported most positively to the **real-world aspect** of the term project (component 1) and affirmed the value of having to **conduct research** and **coming up with their own design goals** (component 2). This result explained why students became more engaged in the redesigned course.

**Tablet 4. Student responses to task factors in revised CPBL during final interview (N=8)**

Term Project Components	Positive Response	Negative Response
1. Consider real-world design and constraints (budget, etc.)*	6	
2. Background research and comp up with your own design goal*.	5	
3. Working with teammate	5	2
4. Discuss design plans with peers	4	1
5. Using OPNET to evaluate the performance of your design plans	3	
6. Writing the report	3	1
7. Preparing a "Promotion flyer" for bidding*	2	

\*New or enhanced elements in the revised CPBL.

## **2) Moving from Surface Approach to Deep Approach**

Well-designed CPBL encourages students to move toward using a deeper learning approach. Based on multiple evidences, the students appeared to focus more on understanding the materials for themselves than simply on completing the assessed work. Most of the students expressed that *“their main goal is to create something that can be used in real world”*. Due to time constraints, a few students adopted a strategic approach to successfully complete the project requirements, but none reported using a surface approach. Clearly, the shift towards deeper learning led to the improved project design performance in the re-designed course.

## **3) Engineering Efficacy**

Overwhelmingly, students reported an increase in their self-efficacy in both the skills developed in class and for their future engineering career. Good team work experience, the design experience, opportunity to communicate their work, and positive feedback from the instructor seemed to boost students’ efficacy in general. Also, students realized that the skills gained in the project experience such as the ability to use OPNET, the ability to do network simulation, communication skills, team skills are important for professionals in engineering. Thus, their confidence in engineering career increased since they feel that they gained better skills to put them *“in good place when get into industry.”* The project experience also helped some students to see the deficiency in their skills, and helped them to identify directions to improve.

## **4) Learning to Learn through CPBL**

One major change we made in the course re-design was to embed relevant learning strategies into the curriculum to increase students’ metacognitive awareness of their own learning process. 76% of post-survey respondents indicated that the class helped them to learn more effectively. Participants of the final interviews reported using the following learning strategies in completing the term project: (1) planning specific steps you need to take in order to be successful, (2) managing time and effort effectively, (3) setting specific goals and deciding what you want to accomplish, (4) monitoring the effectiveness of your study, and (5) evaluating the quality of your work. Particularly, improvement in time management is helpful to address the “lack of time” challenge encountered by many students. This finding is confirmed by the significant finding from the survey suggesting that the redesigned course was successful in increasing students’ metacognitive awareness of their own learning process.

## **Discussion and Conclusions**

The exploratory course redesign process and the data analysis results in the pilot course provided some preliminary answers to the question raised at the beginning of this paper - *how to develop an effective instructional system using PBL for engineering students*. Participatory Design Approach showed great potential in our study due to the following reasons. First, the principle of Participatory Design is similar to engineering design process. Since the student co-designers are senior engineering students who have already had some design experiences, they are quite familiar with the concept. Next, the diverse background of the student co-designers helped to bring different perspectives to build an instructional system to meet the needs of a diverse student body. It is worthwhile to mention that the student co-designers also considered how their

peers might respond to the teaching pedagogy and provided valuable suggestions to mitigate the workload issues.

The positive student response to the revised instructional system highlighted several critical factors for a successful PBL experience, including effective peer collaboration, authentic context of the projects, reflection, articulation, and good scaffolding. To encourage students go beyond the basic requirements of the projects, it is important to keep them motivated. The real-world design challenge, opportunity to develop an ownership of the project, and the perceived value of their efforts are helpful to achieve a high level in student motivation and provide a sense of reward in the learning process. Moving forward, we will continue to refine the Participatory Design Approach through iterative practice and develop working strategies to integrate PBL effectively in other engineering courses.

### **Acknowledgment**

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