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Addressing the Learning Needs of Minority Students in Engineering through Participatory Design

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Abstract

This paper provides a holistic presentation of an interdisciplinary research project sponsored by NSF RIGEE (Research Initiative Grant in Engineering Education) program. Launched in 2013, this collaborative research studied the learning characteristics of minority students in a senior computer engineering course using Collaborative Project-based Learning (CPBL) pedagogy and leveraged the research findings to improve the instructional design using *Participatory Design Approach* to increase the success of underrepresented minority students. During the iterative implementation of the revised CPBL in 2014 and 2015, an embedded single-case study was conducted and multiple forms of data were collected to analyze the impact of the course redesign on (a) course related knowledge and skill outcomes, (b) domain-specific efficacy in relation to situated learning, and (c) student engagement (deep vs. surface learning) and team dynamics. In this paper, quantitative and qualitative data collected over the past three years was analyzed collectively, triangulated, and related to relevant research and theories. This process allowed us to work toward: (1) providing a more generalizable description of our overall findings, (2) gaining a greater understanding of the underlying classroom and course factors and their impact on the development of domain-specific efficacy among minority students, and (3) developing a set of guidelines to effectively incorporate participatory design based on the situated learning framework. The significance of the work presented in this paper highlights the need to accelerate current research on using participatory design as a means to empower minority students in engineering and technology related disciplines.

Introduction

How to increase the success of minority students in underrepresented areas such as engineering presents a significant challenge to education community. In recent years, engineering educators are exploring suitable pedagogical approaches to address the learning needs of underrepresented groups in engineering and one such practice is Project-based Learning (PBL) [1-5]. Among these efforts, an engineering professor and a learning scientist from California State University Los Angeles initiated a collaborative study to examine the impact of collaborative project-based learning (CPBL) on the self-efficacy of traditionally underrepresented minority groups in electrical engineering courses with the support of NSF. 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.

Since 2013, the research effort has produced interesting results that allowed us to better understand the learning characteristics of minority students in the CPBL environment. Some intermediate data were presented in our previous ASEE papers [6]. These findings also laid a solid foundation to perform course redesign using an innovative instructional design method called *participatory design* approach. The redesigned course was offered in spring 2014 and spring 2015, which allowed us to conduct an embedded single-case study and collected multiple forms of data. This paper summarizes the data collected during the three-year project period and provides an in-depth analysis of how students from traditionally underrepresented minority groups respond to the revised CPBL through participatory design approach. The multi-year, cross-case analysis results indicate that participatory design approach was effective in "shaping a curriculum that better fits the learning characteristics of our students"[7], and the resulted CPBL model helped to promote deep learning and achieve better learning outcomes.

Theoretical Frameworks

Situated Learning and Self-efficacy

Numerous studies have counted high self-efficacy and intrinsic motivation as success factors in PBL and engineering in general (see Bédard, et al. 2012 for a detailed literature review [8]). Self-efficacy has been identified as an important factor that influences the learning process and an indicator for educational success. Bandura 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." [9]. Notably, beliefs of personal efficacy are domain-specific and can be fostered through mastery experiences, vicarious learning, and social persuasion. To better understand how domain-specific self-efficacy might be fostered within the context of this study, we took the view from a social constructivist perspective based on situated learning and cognitive apprenticeship.

Mastery experiences are essentially performance accomplishments and in a PBL environment, these can be experienced in the successful production of an artifact that has relevance and adds to the body of work of a community. Vicarious learning is directly related with observing others performing a similar task with success. The social persuasion component of domain-specific self-efficacy revolves around social support in the sense of encouragement and constructive feedback – elements of a community of practice supported by the situated learning framework and PBL. This process can be guided by "cognitive apprenticeship," which is a means of learning-by-doing where the thinking process underlying complex, problem-solving skills is made visible through teaching methods such as modeling, coaching, scaffolding, articulation, and reflection [10-11].

CPBL vs PBL

Collaborative Project-based Learning (CPBL) is a revised PBL model developed by Dong and Warter-Perez [12] to address the specific learning needs of under-prepared minority students. It has been implemented in several engineering courses and a positive impact on student learning has been reported [5,12,13]. CPBL has been further evolved in our research in that the PBL component of the instructional system is nested within a situated learning framework, with a greater emphasis on the cognitive aspect of PBL (see Figure 1).
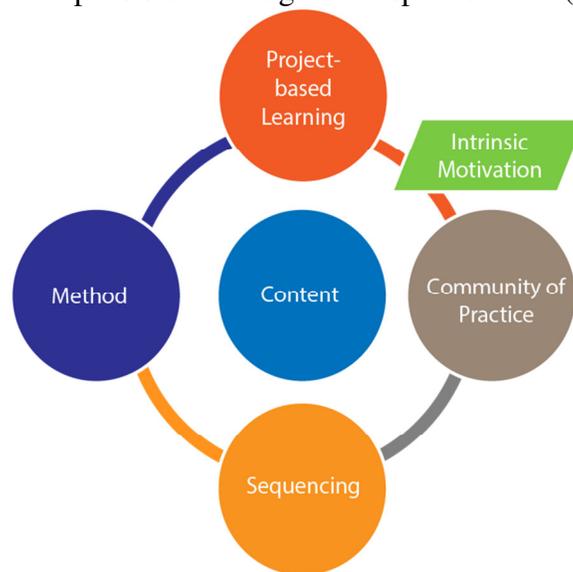

Figure 1. Pedagogical components in CPBL

The blending of domain specific abstract conceptual knowledge and procedural knowledge is a challenge when incorporating aspects of situated learning into a rigorous program where skills not only need to be transferrable beyond the final exam, but there is a necessity for foundational knowledge to advance through the course (such as pass midterms and finals depending on program expectations). In a purely situated learning environment, abstract knowledge may be deemphasized or even denigrated in favor of more procedural knowledge [14]. The CPBL model navigates these waters by using a Cognitive Apprenticeship (CA) paradigm based on its four building blocks: content, methods, sequencing and sociology [11].

CA has its foundation in two main ideas. First, that conceptual and factual knowledge are "learned by being used in a variety of contexts, encouraging both a deeper understanding of the meaning of the concepts and facts themselves, and a rich web of memorable associations between them and the problem solving concepts"[11]. In the CPBL model, this is reflected in the interconnected sociological principles of CA and the characteristics of the course learning environment. The second principle of CA revolves around the focus on cognitive skills and processes rather than physical ones. What the second principle means is that observation and mimicry (in the production of an artifact) alone will not suffice for deep understanding, but the cognitive processes used to produce something need to be transparent and available to the student. As detailed in Chen & Dong [15], the research found that CPBL pedagogy was helpful in reducing the achievement gap for underrepresented minority students, particularly on their efficacy in design, simulation and analysis skills.

Participatory Design

During the research process, CPBL was revised based on *participatory design* [16]. The principle is to involve the end users (which are the students in our case) in every stage of the design process of the instructional system. It is a mutual learning process in which co-designers are empowered to make real and substantial design decisions [16]. This method was selected to redesign our CPBL instructional system because we believe that by engaging the target learners in the design process, a better learning process will be created to fit the needs of our students. 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 [11]. This process involves (1) conducing a needs assessment, (2) translating needs into design goals, (3) prototyping the instructional system, and (4) revising and refining the system. Interested readers can refer to our previous publication for a detailed description of the participatory design process and major curricular changes. 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.

Data Sources and Analysis

Over the past three years, a series of single-case studies were conducted and multiple forms of data were collected[17] (see Table 1), which allowed us to engage in in-depth exploration and analysis of the impact of CPBL and participatory design on different student groups in senior-level engineering classes. The data collected over the past three years using both qualitative and quantitative methods were analyzed collectively, triangulated, and related to relevant research and theories.

Summary of 2013 Results

The baseline data about the original CPBL model (before revision) was collected in 2013. The analysis results of 2013 data 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. It was found that 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, and how to enhance team collaboration and improve time management.

Analysis of quantitative data (pre and post surveys) suggested a high level of general and engineering self-efficacy reported by the students at the start of the course. Independent samples t-tests were computed to compare Hispanic and non-Hispanic pretest scores. No statistically significant differences were found. Although there were no statistically significant differences on the pretest ratings between the groups, Hispanic students consistently exhibited a lower level of self-efficacy compared to non-Hispanics on the pretest ratings (see Table 2 for examples of knowledge and skill outcomes). By the time of the posttest assessment, however, Hispanic students' posttest ratings were very similar and in some cases higher than those of non-Hispanic students.

Table1. Sources of Data and Unit of Analysis

Unit of Analysis	Class	Design Teams	Individuals
Knowledge and skill outcomes	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
Efficacy and Situated Learning	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
Engagement (deep vs. surface learning) and team dynamics	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

Table 2. Examples of knowledge and skill outcomes (2013): overall response from primary research participants: non-Hispanic students vs. Hispanic students (Knowledge was measured on a scale from None (1) to Expert (5); Skills was measured on a scale from strongly disagree (1) to strongly agree (5)

Knowledge Outcome Index	Non-Hispanic Students (n=10)				Hispanic Students (n=5)			
	Pre	Post	Difference	t	Pre	Post	Difference	t
Network simulation+	2.40	4.10	1.70	3.43**	1.40	4.20	2.80	7.48**
Network performance analysis+	2.50	4.20	1.70	3.79**	1.80	4.20	2.40	4.71**
Knowledge of Automatic Repeat reQuest+	2.40	4.00	1.60	4.71***	1.20	3.60	2.40	6.00**
Skill Outcome Index								
Ability to analyze the network performance using simulations+	3.10	4.50	1.40	3.77**	2.20	4.80	2.60	5.10**
Ability to use OPNET to explore and learn new network protocols+	3.00	4.30	1.30	3.54**	1.80	4.60	2.80	3.81**

Note: * p < .05, ** p < .01, ***p < .001.

The dependent samples t-test revealed statistically significant differences between students' pretest and posttest ratings of knowledge and skill outcomes, especially on those items directly related to the project experience. For knowledge outcomes, the ratings on all items were significantly higher on the posttest for Hispanic students, while the differences between pre- and post-test ratings of non-Hispanic students on some of the items were not

significantly different. For skill outcomes, both Hispanic students and non-Hispanic students' pre- and post-test ratings were significantly different on the four items directly related to the project experience.

Results obtained from in-depth qualitative analysis supported the quantitative findings in that the students reported the development of greater level of engineering self-efficacy. Five themes emerged from the data suggested that a high level of student engagement was linked to the social characteristics of the learning environment based on situated learning and cognitive apprenticeship. These themes include:

1) Developing domain-specific self-efficacy in authentic context
2) Learning from multiple perspectives and design scenarios
3) Collaborating through social support
4) Gaining communication and people skills
5) Engaging in deeper learning.

Summary of 2014/2015 Results

The baseline data collected in 2013 provided good inputs to redesign the course using participatory design approach. To evaluate the impact of the revised CPBL, data obtained from spring 2014 and spring 2015 were combined to measure the changes on (a) knowledge and skill outcomes, (b) domain-specific efficacy in relation to situated learning, and (c) student engagement (deep vs. surface learning). For quantitative data, independent and paired samples t-tests were computed to compare students' pre and post self-assessment ratings of knowledge of networking concepts, self-efficacy on content specific skills, and learning strategies. The independent samples t-tests were computed to compare Hispanics to non-Hispanics on the pretest and posttest ratings.

There were statistically significant differences between Hispanics and non-Hispanic students' on three pretest items and on one posttest item. Hispanic students (4.11) were less likely to agree that they felt "at home when working with other engineers" than non-Hispanics (4.77) ((t (20) = 2.53, $p < .05$). The Hispanic students (2.89) were also significantly less likely to agree with the statement "I find it hard to stick to a study schedule" than non-Hispanics (3.23) ((t (20) = 2.48, p < .05). Hispanics (3.38) compared to non-Hispanics (4.15) rated "I try to change the way I study in order to fit the course requirements and the instructor's teaching style" significantly lower (t (20) = 2.12, p < .05). This difference was also present on the posttest, Hispanics (3.63) compared to non-Hispanics (4.54) (t (20) = 2.53, p < .05).

Overall, the paired samples t-test revealed statistically significant differences between students' pretest and posttest ratings of knowledge of networking concepts. Hispanic and non-Hispanic students' ratings on all knowledge of networking concept items were significantly higher on the posttest (see Table 3). Although both groups had significant gains, Hispanic students had larger gains (differences between pretest and posttest ratings) on 10 of the 12 items. For example, the difference between pretest and posttest ratings on "knowledge of computer network design process" for Hispanic students was 2.56 compared to non-Hispanic students, 1.77.

Conversely, there were fewer statistically significant differences in students' pretest posttest ratings on the self-efficacy items. Hispanic students rated the items "I am confident in my computer skills" (pretest= 4.22 vs. posttest= 4.89), "I am confident that I can optimize my network design based on realistic constraints using OPNET" (pretest= 2.67 vs. posttest= 3.89), "I am confident in my ability to use OPNET to explore and learn new network protocols" (pretest= 2.78 vs. posttest= 4.11), and "I am confident that I can analyze the network performance using simulations" (pretest= 3.00 vs. posttest= 4.11) significantly higher. The gains from pretest to posttest ratings were also larger than that of non-Hispanic students.

Similarly, non-Hispanic students' posttest ratings were significantly higher on "I am confident that I can design a network scenario in OPNET" (pretest= 3.38 vs. posttest= 4.54) and "I am confident that I can analyze the network performance using simulations" (pretest= 3.69 vs. posttest= 4.62) significantly higher. Their posttest

ratings on "I am confident in my ability to use OPNET to explore and learn new network protocols" were also significantly higher than the pretest ratings (pretest= 3.46 vs. posttest= 4.31).

Table 3. Examples of knowledge and skill outcomes: overall response from primary research participants: non-Hispanic students vs. Hispanic students (2014 and 2015) (1=Strongly Disagree; 5=Strongly Agree; items with + are directly related to projects).

	Non-Hispanic				Hispanic			
Knowledge Outcome Index	Pre	Post	Difference	t	Pre	Post	Difference	t
Computer network design process	1.38	3.15	1.77	4.48***	0.78	3.22	2.56	5.93***
Network simulation+	1.00	3.15	2.15	5.78***	0.67	3.22	2.56	8.69***
Network performance analysis+	0.92	3.08	2.16	5.11***	1.00	3.22	2.22	10.00***
Data communication model	1.15	3.08	1.93	5.25***	1.13	3.13	2.00	4.73**
Layered network architecture (OSI and TCP/IP model)	1.25	2.92	1.67	4.02**	0.67	3.00	2.33	9.90***
Various data encoding technologies (NRI, Manchester coding)	0.25	3.42	3.17	13.14***	0.56	3.44	2.88	11.09***
Network topology (bus, star, etc.) +	0.92	3.23	2.31	4.63***	1.22	3.56	2.34	8.08***
Knowledge of Automatic Repeat reQuest+	0.58	3.00	2.42	5.35***	0.33	2.78	2.45	10.09***
Knowledge of Ethernet	1.42	3.17	1.75	3.66**	1.67	3.33	1.66	5.00***
How to build and extent a LAN using bridge+	1.00	3.08	2.08	4.52***	0.67	3.22	2.55	14.55***
Knowledge of CSMA/CD+	0.54	2.85	2.31	5.57***	0.33	2.89	2.56	10.55***
Knowledge of OPNET software	0.46	2.92	2.46	7.01***	0.22	3.00	2.73	10.00***
Skill Outcome Index								
Confidence in computer skills	4.67	4.67	0.00	0.00	4.22	4.89	0.67	2.83*
Ability design a network scenario in OPNET+	3.38	4.54	1.16	3.25**	2.78	4.11	1.33	3.27**
Ability to analyze the network performance using simulations+	3.69	4.62	0.93	2.52*	3.00	4.11	1.11	5.55***
Ability to optimize network design based on realistic constraints using OPNET+	3.69	4.31	0.62	1.60	2.67	3.89	1.22	3.77**

Note: * p < .05, ** p < .01, ***p < .001.

Regarding the learning strategy items, only four statistically significant differences were evident. Non-Hispanic students rated the item "I often think about my own learning and thinking process to make sure I understand the material I am studying" (pretest= 4.23 vs. posttest= 4.62), "my main goal in this class is getting a good grade" (pretest= 3.92 vs. posttest= 4.46), and "Usually I make good use of my study time (pretest= 3.77 vs. posttest= 4.31). Finally, non-Hispanic students were significantly less likely to agree that "I find it hard to stick to a study schedule" (pretest= 3.23 vs. posttest= 1.69). Although there was only a few statistically significant difference on the learning strategy items, the majority of the pretest and posttest mean ratings were 4 or higher, 5 being the highest possible. Thus, both Hispanic and non-Hispanic students rated their learning strategies very positively.

Overall Impact of Course Redesign on Project Performance

During the implementation of the revised CPBL model (through Participatory Design Approach) in spring 2014 and spring 2015, we consistently observed significant performance improvement on students' projects compared to that of spring 2013 (before the course redesign). The evaluation of the project performance followed the same criteria in three categories as described in Table 4. The significance of the findings related to students' project performance will be discussed in the next section.

Table 4. Evaluation Criteria of EE440 Term Project

Category 1. Project Goals and High-level Design (20%)	
Criteria: 1. *If the design goals match the realistic needs of the target company?* 2. *If the high-level network design well meet your design goals?*	Measurement: 1. *Design Journal* 2. *Presentation of design goals and high-level design during project meeting*
Category 2. Project Implementation and Simulation (40%)	
Criteria: 1. *If the design is implemented using RiverBed Simulation tool?* 2. *If the simulation scenarios are implemented properly to measure the performance of proposed design?* 3. *If the simulation results are adequate for performance evaluation?* 4. *If the design conclusions are drawn based on thorough and fair evaluation?*	Measurement: 1. Team demonstration of the project 2. *Presentation (project flyer)* 3. *Final project report*
Category 3. Project Presentation/reporting (40%)	
Criteria: 1. *If the project report/presentation adequately documents the design process?* 2. *If the project report/presentation provide clear analysis if the simulation results?* 3. *Quality of presentation (clarity/organization)*	Measurement: 1. *Presentation (project flyer)* 3. *Final project report*

Discussion: Toward a Deeper Learning Approach with CPBL

The major theme that emerged in this study was the students' tendency towards a deeper learning approach in the context of the CPBL course structure. Approaches to learning are generally categorized as a deep approach and a surface approach and this refers to how a student tackles an academic task based on the perceived needs to accomplish his or her goals [18]. For example, if the intention of a student is to simply "pass" a multiple choice quiz, a surface approach might be employed vs. a student who would need to explain a concept to classmates and answer questions after the session would more likely employ a deep learning approach to have a greater understanding of the materials.

The deep learning approach involves an active learning process with intent to understand meaning and relationships within the study material, intrinsic motivation, and the development of new ideas. "There is an internal emphasis where the learner personalizes the task, making it meaningful to his or her own experience and to the real world" [19]. In contrast, the learners' intent is generally based on extrinsic motivational factors. "The learner who uses a surface approach perceives the task as a demand to be met, tends to memorize discrete facts, reproduces terms and procedures through rote learning, and views a particular task in isolation from other tasks and from real life as a whole" [19]. These two approaches "lead to qualitatively different learning outcomes" [18]. This qualitative difference in students' learning outcomes was reflected in the projects designed by the students.

Figure 2 compares the features of three projects which won the best design award in three implementation terms. In spring 2013, most of the project teams set up their design goals just based on the number of users in the company and the budget constraints, which are fundamental factors in networking design. The design product shown in Figure 2. A scored high due to the solid implementation, convincing simulation results and excellent presentation in project report. However, since the proposed network only considered the capacity and

cost, its value is very limited for a real company seeking a working network solution. Since spring 2014, the revised CPBL incorporated research components that required the student teams to investigate and identify the network needs of a target business before setting up the design goal. Along with the contest component, the student teams seemed to be motivated to explore and consider a lot more realistic design factors to make the proposed network solution more reliable, more secure, and more user friendly. Advanced design factors, such as reliability, mobility, and security, were considered in 2014 and 2015 project design products (Figure 2.B and Figure 2.C1) besides capacity and cost. Consequently, the teams developed better skills using network simulator to create and evaluate more realistic network scenarios (e.g. link failure), which are valuable in professional practice. Specifically as shown in Figure 2. C2, the 2015 project team also considered the geographical layout of the target company in their design process, which resulted in a very practical network solution.

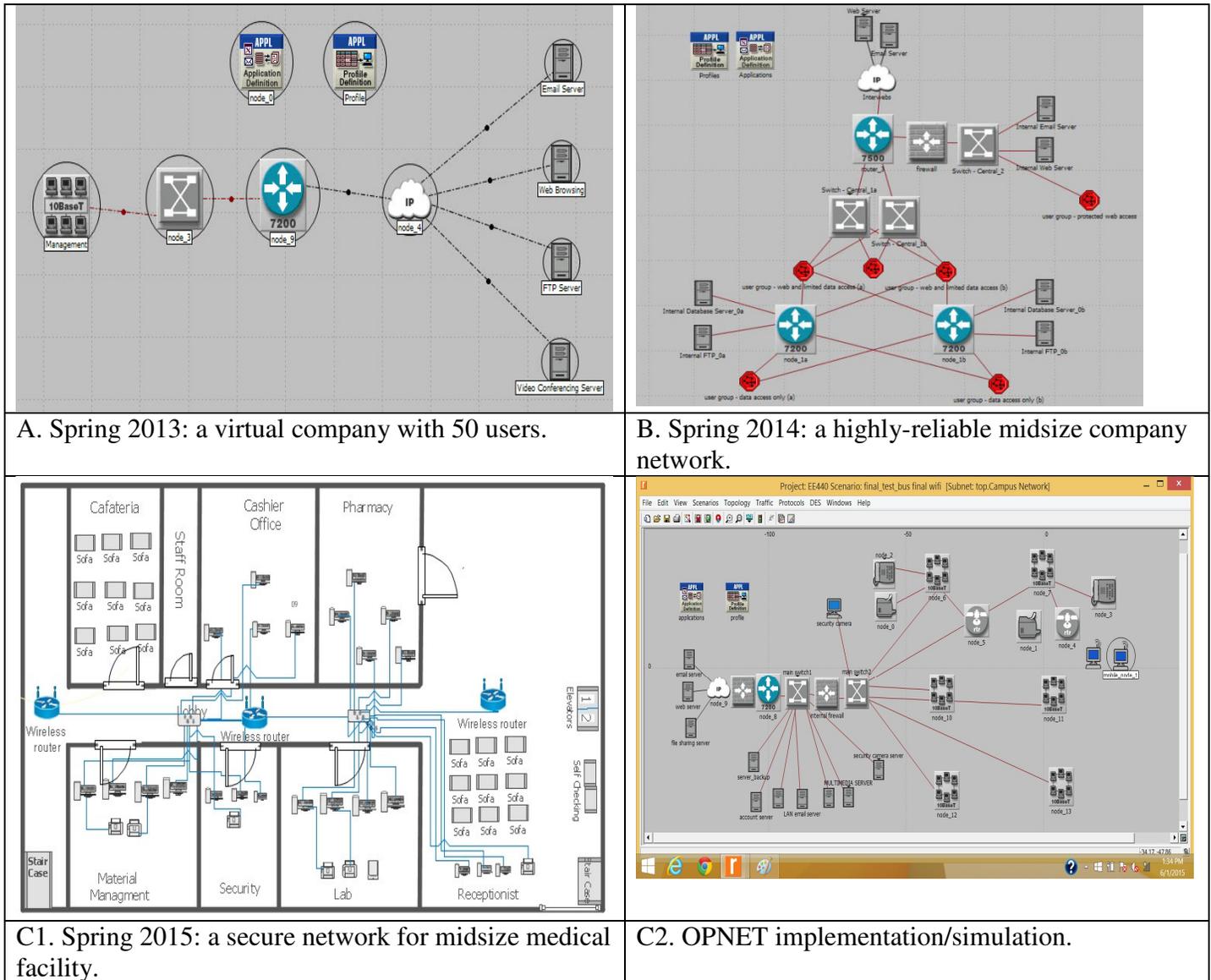| A. Spring 2013: a virtual company with 50 users.	B. Spring 2014: a highly-reliable midsize company network.
C1. Spring 2015: a secure network for midsize medical facility.	C2. OPNET implementation/simulation.

Figure 2. Side-by-side comparison of the best design product in 2013 (A), 2014 (B), and 2015 (C1 and C2).

As specified in ABET student outcomes, it is crucial for us to design a proper learning process for engineering students to develop design skills under realistic constrains (economic, environmental, safety, etc.). The improvement in the demonstrated design performance indicates that the revised CPBL model has been effective on this aspect.

Based on quantitative analysis, the CPBL model was found to be effective across three years of data. We consistently found that all students rated their knowledge and skills significantly higher as a result of the CPBL

experience. Hispanic students, however, appear to have had larger gains (self-ratings) in their knowledge and skills compared to non-Hispanics. Qualitative analysis further revealed a qualitative difference in students' learning outcomes as a result of adopting the redesigned CPBL model. Students' projects were found to be more complex and realistic, indicating a deeper and more active learning approach was employed.

According to earlier cognitive scientists Rumelhart and Norman's study [20], three modes of learning, accretion, restructuring, and tuning provide a useful framework to account for different levels of learning (i.e., surface vs deep learning). *Accretion* refers to the accumulation of knowledge in one's knowledge base; *restructuring* refers to the reorganization of one's existing knowledge structure; and *tuning* refers to a continuing modification of the existing knowledge structure to improve the accuracy, generalizability, and specificity. While the process of accretion yields quantitative changes of one's knowledge base, the processes of restructuring and tuning account for the emergent quality of complex (deep) learning. Stated differently, knowledge accretion demands little effort and represents the simplest mode of learning, whereas knowledge restructuring involves a complex structural or qualitative changes. This complex learning process can be described as "a 'click of comprehension,' a reasonably strong feeling of insight or understanding of a topic that makes a large body of previously acquired (but ill-structured) information fit into place" [20].

Hall, Ramsay and Raven [21] pointed out that "high-quality learning outcomes, such as analytical and conceptual thinking skills, may not be achieved unless students are encouraged to adopt deep approaches to learning" [21]. Furthermore, much of the research into learning approaches arguably [19] suggests that these are learning techniques that students will employ based on the situation rather than a predisposition and thus the deep approach can be enticed through course structure and assessment methods [21]. As it became clear to us in our research effort, we sought to leverage our student response and the elements based on CPBL to promote a deep learning environment.

Conclusion

Overall, the research work completed through the interdisciplinary collaboration was productive with several milestone tasks completed, including an established participatory design process, the creation and piloting of a learning strategy website, and the development and validation of research instruments and protocols based on the situated learning framework. The quantitative and qualitative data collected during the iterative implementation process of revised CPBL in 2014 and 2015 confirmed the positive responses for both Hispanic and non-Hispanic students to this pedagogy. The consistent performance improvement in the term projects demonstrated that the revised CPBL helped to keep students motived in the design process and achieve goals at a higher level.

The consistent data analysis results also validated participatory design as an effective instructional design method to improve the student learning experiences in engineering courses. While the literature on participatory design approach reported mixed results, we found that a successful design required 1) a diverse cohort of co-designers who can represents a broad perspectives of students' opinion; 2) a thorough analysis of "what need to be changed", and link it with student learning characteristic; 3) a suitable theoretical framework to guide the instructional design. Moving forward, we will disseminate our research findings with other colleagues and seek opportunity to extend the revised CPBL model as well as the participatory design approach in other engineering courses.

Acknowledgments

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