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The Instructional Design and Effects of Capstone Project Course Embedded Inquiry-Based Learning in Technical High School*

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In capstone curriculums at the senior high school stage of technical high schools, capstone projects are required for students to produce the final product in the end of class. This study was designed to explore the effect of applying an inquiry-based learning (IBL) teaching strategy into capstone projects (CP-IBL) to promote students' inquiry ability and creative thinking. Students in two classes of a three-year major in electrical engineering participated. One class was assigned to an experimental group that was facilitated by a CP-IBL strategy emphasizing inquiry ability and creative thinking, while in the control group was taught with a traditional lecturing approach. There were seven stages used, including engagement, question, design, discussion, production, evaluation, and revision as the main framework for the experimental group, which was implemented in CP-IBL. Using a quasi-experimental research approach, ANCOVA analyses of abilities measures pre- and post- teaching showed inquiry ability and creative thinking of the experimental groups was significantly better than that of the control group.

Keywords: inquiry-based learning (IBL), capstone project, quasi-experiment design, creative thinking ability, inquiry ability, IBL embedded in capstone project (CP-IBL)

Introduction

Inquiry-based learning (IBL) is a learner-centered pedagogy in which students play an active part in the process of knowledge discovery or acquisition (Fernandez, Mesquita, Flores, & Lima, 2014). Pedaste and Sarapuu (2006) referred to IBL as an approach in which learners solve problems by using their inquiry skills. IBL is offered as an effective framework for catalyzing positive shifts in learning processes and strategies (Buck Institute of Education, 2014; Thomas, 2000). IBL also allows students to make determinations about the problems, challenges, and issues they investigate, helping move students toward meaningful engagement and deeper learning (Pedaste et al., 2015). It has been found that greater autonomy through IBL helps students develop knowledge and process skills (Small, 2009) as well as self-efficacy (Fernandez et al., 2014), self-confidence, as they work and learn through questioning and problem-solving (Nunex & Leon, 2015).

Several quantitative studies support the effectiveness of IBL as an instructional approach. Furtak, Seidel, Iverson, and Briggs (2012), for example, incorporated studies by using a broad range of terms to describe IBL (e.g., mastery learning and constructivist teaching); they reported an overall mean effect size of 0.50 in favor of the inquiry approach over traditional instruction. A meta-analysis by Alfieri, Brooks, Aldrich, and Tenenbaum

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(2011), they performed a meta-analysis comparing inquiry to other forms of instruction, such as direct instruction or unassisted discovery, and found that inquiry teaching resulted in better learning (mean effect size of d = 0.30). A positive trend supporting inquiry-based science instruction over traditional teaching methods was found in a research synthesis by Fortus, Dershimer, Krajcik, Marx, and Mamlok-Naaman (2004), Fernandez et al. (2014), and Minner, Levy, and Century (2010).

Despite many above studies point out that although IBL enables students to develop innovation and discrimination abilities, however, it focuses mostly on the experiment process for theory verification and is less used in practical courses. This includes capstone projects that produce a real product. While didactic teaching featuring one-way lectures of teachers and passive knowledge receiving of students was commonly practiced in the past, the resulting learning motivation was low. Additionally, according to the Technical High School's Standard of Curriculum (Ministry of Education, 2009) wrote a vision of science education, which emphasizes science and engineering content knowledge must be integrated and implemented in the classroom through scientific inquiry and engineering design. Yet, many classroom teachers struggle with this integral pedagogy in their science classrooms. It has been well documented that traditional methods of instruction, including lectures, are a passive style of learning and offer little to help students construct an understanding of scientific content, concepts, and relationships (DiBiase & McDonald, 2015). However, IBL must first make sense to teachers, so that they will use it out of a genuine desire to do so, not just because the standards say so.

The teachers who in capstone project may then encourage students by team to choose specific topics that interest or inspire them, such as projects related to their personal interests or career aspirations (Turner & Pidcock, 2006). According to the Glossary of Education Reform (2016) definition, capstone project—also referred to as project work, culminating project, or senior exhibition, among many other terms—is a multifaceted assignment that serves as a culminating academic and intellectual experience for students. It is completed typically during their final year of high school, or at the end of an academic program or learning-pathway experience. While similar in some ways to a college thesis, capstone projects may take a wide variety of forms, but most are long-term investigative projects that culminate in a final product, presentation, or performance. For example, students may be asked to select a topic, profession, or social problem that interests them, conduct research on the subject, maintain a portfolio of findings or results, create a final product demonstrating their learning acquisition or conclusions (e.g., a paper, short film, or multimedia presentation), and give an oral presentation on the project to a panel of teachers, experts, and community members who collectively evaluate its quality (Turner & Pidcock, 2006). Capstone projects are an integrated technology program in the technical high schools of Taiwan. It is a required course in the last year of technical high schools and the capstone course that demonstrates what students have acquired from the professional theories and practical courses from Grades 10-12. Therefore, students are required to produce a finished product in the capstone project. However, most students' replicate textbook examples or unrelated real-life objects to fulfill the credit requirements for graduation. The outcomes are either uncreative or more costly than those sold in the market.

Based on the purposes of capstone project which were set at several high schools by reviewing their manual or instruction guide, we may conclude the students' abilities, will be cultivated, including connection to magnet theme, initiative, self-direction, and accountability, clear and effective communication, citizenship and responsibility, accessing and analyzing information, problem-solving and critical thinking, presentation et al. (Fall Creek High School, 2018; Hill Regional Career Magnet High School, 2017; Independent High School, 2018; Woodstock High School, 2015). However, students also face many obstacles during course learning, including being unable to find a considerable theme, are without any sponsors for advisements or financial support (Steinlicht & Garry, 2014), the responsibilities are unclear within the team, they do not know how to collect available information, do not know how to finish the product using outside resources, etc. Additionally, no evidence has been provided on the positive effects of multidisciplinary capstone projects (Moon-Soo, 2017). Nevertheless, many past studies have pointed out that IBL has the advantages of cultivating students' problem-solving skills (Pedaste & Sarapuu, 2006), meaningful engagement, and deeper learning (Pedaste et al., 2015), and increasing their self-efficacy and self-confidence (Fernandez et al., 2014). It perhaps can overcome the obstacles mentioned above in the capstone project by IBL. Based on above reasons, using IBL embedded in capstone project course should be a more realistic teaching strategy in regards to its use in this study.

According to the IBL theory and comparing the procedures of capstone project, after finding a topic from their past experience, students will start a process comprising planning and idea development, design research, functional analysis, recordation of test results, and presentation of works. As the inquiry process repeats in this process, IBL fits this nature. Based on IBL and by examining students as the research subject and teachers as the helpers, this study enabled students to develop topics from the daily life or industry-related issues, integrate the theories and professional competencies acquired in the past, and enrich practical experiences by enhancing students' motivations through collaboration and practice. Therefore, this research seeks to improve the capstone projects that are implemented by teachers and students with insufficient knowledge and skills on IBL in technical high schools, exploring the teaching effects on IBL embedded in capstone project, and extending IBL features into real-world products. Thus, the purpose of this study was to use experimental teaching to enhance the IBL ability of students and further develop their creative thinking ability through group collaboration, real experience, and practice.

Theory Background

Evidence-Based Teaching Method

When implementing IBL, teachers should understand the contents, models, and related theories of IBL, in order to integrate IBL with their education beliefs and thinking in instructional design. Evidence-based learning (EBL) and constructivist learning theories are the most important. Traditionally, teacher-based or textbook-based instructions were emphasized. However, related studies suggest that education-job mismatch arises when this way of teaching is used in professional fields (Thomas, 2000). Furthermore, Ravitz et al. (2004) believed that didactic teaching cannot create opportunities of proactive and voluntary learning for students, while EBL is one of the methods to develop IBL in students. In EBL, teachers and students must co-simulate scenarios in reality for students to explain and describe these scenarios based on the results that students observe from the evidence found in the scenarios after acquiring basic knowledge. Therefore, EBL enables students to develop correct comprehension (Chinn & Malhotra, 2002). In addition, students can improve their critical thinking and problem-solving abilities with EBL to help them make correct decisions in professional fields (Jarvis, 2004). ELB is characterized by traits including: (a) engagement in problems in professional fields; (b) thinking of evidence causing problems; (c) conclusion of organized explanations based on evidence; (d) linking professional knowledge; and (e) spreading knowledge and verifying results. These traits turn teachers into instruction facilitators, enable students to have direct learning, and improve the attitude and interests of students.

Constructivist Learning Theory

Constructivist learning theories form the psychological framework of IBL (Yen, 2004). According to constructivism, "Knowledge is the active construction rather than the passive acceptance or absorption of a cognitive individual". It emphasizes the role change and responsibility shift between teachers and students. Such a change and shift turn students into the interpreter, creator, and inventor of knowledge and the inquirer of problems. In return, the role of teachers will shift to the designer of problems and scenarios, the educator and moderator of discussions and communication, and the facilitator of knowledge construction. When learners actively construct knowledge and teachers should start with the present experience of learners (Huang, 2015). Teachers should also emphasize the importance of IBL for learners to increase "thinking" and "doing" experience when asking questions, explaining, and communicating and sharing with others. Starting with the scenarios and using the contents in everyday life are the only ways to enable students to learn effectively through actively discovering problems in the inquiry process, and thereby, construct their own knowledge and concepts (Chou & Chang, 2012). According to the research conducted by Kilinç (2007), IBL provides opportunities for students to: (a) develop skills they will need all their lives; (b) learn to cope with problems that may not have clear solutions; (c) deal with changes and challenges to understandings; and (d) shape their search for solutions, now and in the future (Kilinç, 2007).

Based on the above theoretical bases, this study defines IBL as the assistance of students in exploring and resolving problems with students as the subject and teachers as the helper. First, a teacher must understand the goal and content of teaching and design an inquiry model with difficulty appropriate to students. Then, teachers should guide students to discover problems and assist them in drawing up appropriate research plans and problem-solving methods. Lastly, students should conduct experiments to find solutions to a problem and provide a conclusion and explanation. Teachers should emphasize more the importance of inquiry from teaching for learners to discourse with teachers and other students, and thereby, infer and discover new knowledge and principles with pre-existing knowledge. This is done in order to develop the ability to learn, discover, and resolve problems voluntarily by students.

Learning Satisfaction Theory

The learning satisfactory theory is originated from the customer satisfaction theory, which is advanced by Cardozo (1965). In marketing perspective, each curriculum is as one product, and students are the main customers of school that their individual needs have to be fulfilled. To attract more students to participate in capstone courses, the teaching services provided by high schools should consider how to enhance and improve their service quality and students' learning satisfaction (Wu, Hsieh, & Lu, 2015). Learning satisfaction can be viewed as comparative outcomes between expectancy and perceived service with pleasure or displeasure (Oliver, 1999). Furthermore, learning satisfaction theory believes that students are the consumers of education products and they have the rights of investing in any learning institute they like. In previous studies on student learning satisfaction, the quality of service, quality of teaching, and quality of the engagement in the learning environment are related to the students' satisfactions and successful learning outcomes have been explored (Knight, 2002). After reviewing the previous articles, there is strong empirical evidence showing that higher levels of satisfaction lead to decreased levels of negative word-of-mouth dissemination and complaint behavior, and increased repurchase intentions (Smith & Bolton, 1998; Andreassen, 2001). Nonetheless, there are seldom articles researching the learning satisfaction outside of experimental teaching effects. Thus, in addition to exploring the effects of experimental teaching, this study also implements an investigation into learning satisfaction.

Out-of-Classroom Inquiry Learning

The most basic form of support in formal and informal learning is direct instruction. IBL, especially when it takes place in out-of-the-classroom in practice workshop settings, is based on ill-structured inquiry activities that require a great amount of support and guidance from the facilitators. These types of mobile activities facilitate such support even when participants are distributed across different locations in technical high schools. In general, this includes the areas of materials, operations, instruction, demoing, etc. Based on the Suárez, Specht, Prinsen, Kalz, and Ternier's (2018) study, there is a continuum of direct instruction and guidance that works on different levels (location guidance, procedures, and meta-cognition). According to the definition of procedural guidance on IBL by Suárez et al. (2018), the direct instruction through procedural guidance helps the learner carry out an activity or process, and helps learners in executing and auto-matizing step-by-step processes (Suárez et al., 2018) that are available in this study. For example, in Hsiao, Chang, Lin, and Wang (2016) and Suarez, Ternier, Kalz, and Specht (2015), learners received question-guided instruction in order to help them during the data collection process and with data analysis. Other examples used list items to guide specific parts of the inquiry process (Anastopoulou et al., 2012). Regarding the guidance of procedure, the learners do have more autonomy in finishing their project. However, their control over actions, strategies, and goals is limited by this step-by-step guidance (Suárez et al., 2018). For example, with regards to brainstorming for potential topics for capstone projects, teachers guide students to have a personal appreciation for the topic through relevant elements in their daily life to stimulate their motivation for learning and use the capstone as a means to take students move beyond the confines of their schools to enter the real market (i.e., communities, stores, and so forth), so that students can see for themselves and discover market demand before they apply the knowledge they have learned to resolve the problem in the market. This would help students to train their capacity to identify opportunities, inquiry, and problem-solving abilities (Chang & Chou, 2018). In this case, the types of mobile activities also help learners to monitor and reflect upon their learning. In a case, like in Suarez et al's. (2015), learners could visualize their performance after the activity, so they could reflect upon their actions.

Research Design

Aiming to meet the professional needs of workplaces, capstone projects can develop the problem-solving, creative, and integration abilities for students in technical high schools. This allows them to independently collect data and have preliminary applications of the professional competencies acquired from their respective schools (Wu & Lyau, 2010). In class, students finish a capstone project either independently or in a group. In one research paper, Ernst, Segedin, Clark, and DeLuca (2014) found that teaching methods featuring repeated training and improvement will help students improve their performance, reflection, and critical thinking abilities. Therefore, based on the theory of IBL, the results of experimental teaching in capstone projects enable students to combine theories with practice for future application in the industry.

Teaching Framework

After reviewing the literature relating to IBL, this study proposed a preliminary CP-IBL teaching framework comprised of seven stages: engagement, question, design, discussion, production, evaluation, and revision. To adapt this model to the capstone project of technical high schools, this study invited six senior IBL experts with an average of 20 years of experience to discuss the model and revise it into the following seven stages: "engagement, question, design, discussion, production, evaluation, and revision" to serve as the main framework of instructional design. First, the course teacher examined the pre-existing knowledge of students before explaining the process with electronic data files, including text stencils, pictures, and videos. After students acquired a general idea of the unit contents, the course teacher gave a demonstration before allowing students to operate independently. Then, the experimental group continued with the group discussion and independent research, while the control group implemented an imitation practice based on the topic planned by the teacher. After the end of practice teaching, students of the experimental group shared their outcomes and experiment experience with other students, while the control group simply handed out their capstone project.

Instructional Design

89S51 Express—Happy Entry by Jiang (2014) and *89S51 Illustrated—C Language* by Chang, Wang, Hsu, and Yi (2015) were the textbooks used in the curriculum. The same course teacher of the Electrical Engineering Section administered the experimental teaching on both the experimental and control groups. CP-IBL was applied to the experimental group, while traditional didactic teaching was used in the control group. CP-IBL teaching was implemented in four lessons each week, 45 minutes each lesson, over eight weeks, conducted from weeks 1 to 8 of the second semester of academic year 2015. Table 1 shows the instructional design described below.

Table 1

Instructional Design: Didactic Teaching vs. CP-IBL

Week	Didactic teaching		CP-IBL	
	Unit	Syllabus	Syllabus	Description
1	Course overview	Describing course contents and group division.	Describing the contents and important points of the course; Group division (1-3 students/group) Understanding the prior competence of students; Pre-test.	Effectively connecting the pre-existing and new knowledge in students with daily life experience and capturing the professional new knowledge and industrial trends of the course taught.
2	Project conceptualization	Explaining research concepts and research questions.	Guiding students to propose interested fields and develop the concept of research questions; Guiding students to confirm the research questions.	Emphasizing the important concepts, principles, or skills of each unit; Asking students to present the process of concept formation and research question development.
3	Software design for circuit making (understanding Keil C programming framework) (I)	Teachers set the topic and demonstrate operation.	Setting the research topic based on the field(s) that interest(s) students; Proposing research hypotheses by students; Understanding the operating skills of students; Understanding problems of students and clarifying their concepts.	Describing the required equipment and resources relating to the research topic. Providing examples with explanations or demonstrations; Assisting students in making research hypotheses and concluding the foci of learning; Clarifying misconceptions and rectifying the important concepts and skills acquired by students.
4	Hardware design for circuit making (operation and application of μVision) (I)	Teachers set the research questions, propose research hypotheses, and demonstrate operating skills.	Setting the research topic based on the field(s) that interest(s) students; Proposing research hypotheses by students; Understanding the operating skills of students; Understanding problems of students and clarifying their concepts.	Describing the required equipment and resources relating to the research topic. Providing examples with explanations or demonstrations; Assisting students on making research hypotheses and concluding the foci of learning; Clarifying misconceptions and rectifying the important concepts and skills acquired by students.

(Table 1 to be continued)

5	Software design for circuit making (essentials for programming with Keil C) (II)	Operation demonstration, student operation, and teacher explanation.	Reviewing information gathered by students; Confirming the research hypotheses made by students; Understanding the operating skills of students; Understanding difference between the prediction and outcomes of research of students; Understanding the research limitations of students; Peer-interaction and experience sharing.	Motivating students and maintaining their learning interests by asking them to search for related information, such as award-winning or patented works; Helping students to confirming research hypotheses; Progressively demonstrating practice and asking students to practice; Adjusting teaching methods or contents based on the difference of individual students; Giving sufficient time for students to operate and practice, and giving them appropriate feedback.
6	Hardware design for circuit making (operation and application of µVision) (II)	Operation demonstration, student operation, and teacher explanation.	Reviewing information gathered by students; Confirming the research hypotheses made by students; Understanding the operating skills of students; Understanding difference between the prediction and outcomes of research of students; Understanding the research limitations of students; Peer-interaction and experience sharing.	Motivating students and maintaining their learning interests by asking them to search for related information, such as award-winning or patented works; Helping students to confirming research hypotheses; Progressively demonstrating practice and asking students to practice; Adjusting teaching methods or contents based on the difference of individual students; Giving sufficient time for students to operate and practice, and giving them appropriate feedback.
7	Completing circuit and functionality tests (s51_pgm linking test)	Submission and review of outcomes, and teacher evaluation.	Reviewing the research outcomes of students; Understanding the operating skills of students; Reviewing the suitability of student comments and their degree of understanding.	Selecting suitable evaluation methods based on the unit and teaching goals; Understanding the experiment mastery of students based on the research outcomes; Observing students' comments on the research outcomes of other groups.
8	Capstone project production and modification	Submission and review of outcomes, and teacher evaluation.	Reviewing the research outcomes of students; Reviewing the suitability of student comments and their degree of understanding; Understanding the concepts acquired by students in the research; Reviewing the subsequent modifications of research outcomes by students; Post-test.	Proposing the events or competitions for students to participate and future research directions, and asking students to submit the revised capstone project report to share their experience with others.

Notes. 1. Underlined contents are CP-IBL contents; others are common elements to both didactic teaching and IBL;
2. Keil C is the advanced language for programming applications for the 89S51 single chip;
µVision is a program for programming Keil C.
s51_ pgm is the communicator for the Keil C programming language and the 89S51 single chip (burning C language to 89S51).

Participants and Setting

The capstone project can be regarded as a capstone course that is taught in the last year in senior high schools. All of the subjects' ages range from 17-18 years old in the study. This study adopted a quasi-experimental design for experimental teaching. The research objects used in this study are randomly assigned to students in existing technical high school classes. One class is the experimental group and the other one class is the control group. There is no deliberate increase or decrease in the number of students. Because

Taiwan’s new birthrate is quite low and the number of schools is still quite large, many middle school students have chosen to attend high school. Therefore, in technical high schools, the average number of students in a class has dropped to 12-20.

This quasi-experimental study divided students at random into the experiential group and the control group, including 13 students in the experimental group and 14 students in the control group. In order to compare the effects of the experimental teaching on both groups, this study conducted a pre-test with the “Inquiry Ability and Creative Thinking Inventories” before the experimental teaching to understand the initial behavioral condition of students. After the eight-week experiment, in which traditional didactic teaching was implemented on the control group and IBL on the experimental group, this study conducted a post-test with the “Inquiry Ability and Creative Thinking Inventories” to measure the behavioral change of students. Then, this study measured the IBL satisfaction of students in the experimental group with the “Learning Satisfaction Questionnaire”.

Beginning of the Teaching

Before being divided into groups, students were informed of the group division methods, industrial trends, and capstone project production process for them to understand the goal and method of the curriculum. At the beginning, µVision (including project management, programming, simulation, and debugging) and the direction of research topic exploration were introduced to students. For example, before operating the AT56S51 circuit board, students must download and install related packages (µVision and s51_pgm) with the computer for students to understand the program framework and editing essentials. At this stage, students are the subject, while teachers are the helper. When students explored and discerned micro-processors and the AT89S51, teachers helped them understand current industrial trends and the equipment currently used in the industry. Teachers also assisted students by consulting with them on related data and discussed the applied solutions or ideas with students.

During the Teaching

In the middle of teaching, basic and advanced techniques were the focus. Teachers explained basic functions to students with simple examples before simulating the creation and designing new applications. Take understanding the program framework and editing essentials of Keil C for example. In the programming course, teachers started with explaining the meaning of program codes to students before programming such codes for students to explore and understand the contents more easily. In the hardware design course, teachers began with the structure and functions of circuit templates for students to link program codes with hardware circuit templates more easily before conducting integrated tests after completing the unit. In order to find solutions in the capstone project, students discussed and analyzed problems, and teachers help them verify concept accuracy.

End of the Teaching

Towards the end of the teaching portion, all software and hardware course units were integrated and an overall test was conducted. Students inquired voluntarily and discussed how to achieve system operation and devise an innovative design in different scenarios by flexibly using what they had acquired. For example, the prototype (target board) design was the main task of hardware, while turning programs into executable codes (firmware) through programming (using Keil C in the curriculum) and re-construction (compilation and linking) was the prime target of the software. Then, students debugged or simulated the outcomes. After this curriculum, students can compose phone ringtones and music box sounds with the simulation board. Peer-discussions and comments were conducted on the outcomes afterwards. In addition, teachers can explore the learning attitude of students and recommend modifications based on the research outcomes. After modifying their works based on the teacher's recommendations, students can participate in research paper and capstone project competitions with their respective modified capstone projects.

Instrument

This study aims to investigate the effects of CP-IBL on students in the capstone project course with the following research instruments: (a) Creativity Assessment Packet (CAP) adapted by Lin and Wang (1994) from Williams (1970)'s CAP; (b) the "Creative Thinking Ability Inventories" adapted by this study to actual needs of students from the "Creative Ideas and Design Ability Inventories" by Chang (2011); (c) the "Inquiry Ability Inventories" adapted by this study for use on technical high schools from the "Inquiry Ability Inventories for Horticulture-Majored Students of Senior High Vocational Schools" by Huang (2015); and (d) the "Learning Satisfaction Questionnaire" was developed by Huang (2015) in his original scale "Cooperative Learning Satisfaction Questionnaire for Capstone Project of University Engineering Departments". According to the definition of Huang (2015), there are four dimensions in learning satisfaction questionnaire: cognition construct, skills construct, affection construct, and creativity construct. Therefore, we adopted and revised it for compliance with the content and situations that were to be measured in this study.

Learning Satisfaction Questionnaire

In order to measure the degree of satisfaction with IBL of the experimental group, this study developed the "Learning Satisfaction Questionnaire" in respect to the "Cooperative Learning Satisfaction Questionnaire for Capstone Project of University Engineering Departments" by Huang (2015). The questionnaire falls into four constructs: cognition, skills, affection, and creativity. The five-point Likert scale was also applied, where "5" represents "Highly satisfied", "4" represents "Satisfied", "3" represents "Fair", "2" represents "Unsatisfied", and "1" represents "Highly unsatisfied".

This study also invited four experts to correct questionnaire items based on the research subject matter. In results, item 16 in the affection construct was removed; and items 26 and 27 and items 28 and 29 in the original version with similar meanings in the creativity construct were combined as items 25 and 26, respectively. The answer results showed that the internal reliability is 0.879 for the cognition construct, 0.808 for the skills construct, 0.886 for the affection construct, and 0.804 for the creativity construct; and the total inventory reliability is 0.942. Factor analysis found that the total variance explained is 95.02%.

Findings

After analyzing, if there is significant difference in the initial behavior of both groups by conducting an independent-sample *t*-test on the results of the inquiry ability pre-test, this study conducted the test of homogeneity of regression slope within groups by setting different teaching methods as the fixed factors, the inquiry ability pre-test results of both groups as the covariate, and the inquiry ability post-test results as the dependent variable. After eliminating the influence of the covariate, the one-way ANCOVA was conducted to analyze if there is significant difference in the inquiry ability between both groups after the experimental teaching in order to analyze the learning efficacy of CP-IBL and traditional didactic teaching.

Analysis of Inquiry Ability Results

Table 2 shows that the difference in inquiry ability between both groups is insignificant as found in the independent-sample *t*-test on the results of the inquiry ability pre-test. This suggests that the initial behavioral difference both groups of students are insignificant and both groups are behaviorally similar. A test of homogeneity of regression slope within groups was conducted after the experimental teaching. If both groups are homogenous, the homogeneity assumption is not violated, suggesting that the null hypothesis is accepted. After eliminating the influence of the covariate of inquiry ability, the one-way ANCOVA was conducted to compare if there is significant difference between both groups in the inquiry ability post-test.

Table 2

Summary of the Independent-Sample T-Test of Inquiry Ability Pre-test of Both Groups

Group	The number of participants	Mean	SD	*t*-value	*p*-value
The experimental group	13	70.00	8.367	-0.304	0.763
The control group	14	71.14	10.876		

With significance level $\alpha = 0.05$, Table 3 shows the test of within-subject effects, i.e., the summary of the test of homonymy of regression coefficient within groups. The results of the test of homonymy of regression coefficient within groups (Teaching method * Inquiry ability pre-test) are $F = 0.152$ and $p = 0.700 > 0.05$l, below the significance level. Therefore, null hypotheses should be accepted and alternative hypotheses should be rejected in the statistical test. This suggests that the regression slope of both groups is identical and parallel to each other after eliminating the influence of the IBL pre-test. As this complies with the assumption in the analysis of covariance—assumption of homogeneity of regression coefficients within groups, the analysis of covariance can continue.

Table 3

Test of Homogeneity of Regression Coefficients Within Groups After Eliminating the Influence of IBL Pre-test of Both Groups

Regression coefficients within groups	Type III sum of squares	*F*-value	*p*-value
Teaching method	12.883	0.291	0.595
Inquiry ability pre-test	258.288	5.829*	0.024
Teaching method * Inquiry ability pre-test	6.736	0.152	0.700

Note. $^{*}p < 0.05$.

Table 4

Summary of the Analysis of Covariance Within Groups After Eliminating the Influence of Inquiry Ability Pre-test

Source	Type III sum of squares	Mean of sum of squares	*F*-value	*p*-value	Eta square
Corrected mode	1,662.189a	831.095	19.444*	0.000	0.618
Intercept	45.997	45.997	1.076	0.310	0.043
Inquiry ability pre-test	1,416.849	1,416.849	33.149*	0.000	0.580
Teaching method	337.481	337.481	7.896*	0.010	0.248
Error	1,025.811	42.742			

Note. $^{*}p < 0.05$.

Table 4 shows the test of dependent variables of both groups, i.e., the summary of the analysis of covariance. The results of the analysis of covariance are: $F = 7.896$ and $p = 0.01 < 0.05$. They suggest that after eliminating the influence of the inquiry ability pre-test, the processing effect of the experimental group is significant, and its inquiry ability (adjusted mean = 81.012) is significantly higher than that of the control group (adjusted mean = 73.917). In the analysis of covariance, instead of the post-test results of the experimental and control groups, it is to compare the adjusted mean of both groups after eliminating the influence of the pre-test.

Analysis of the Results of Creative Thinking Ability

Table 5 shows that no significant difference between the experimental and control groups in the independent-sample *t*-test on the results of the creative thinking ability pre-test, suggesting that the difference in the initial behavior of both groups is insignificant, i.e., they are similar groups. After the experiment teaching post-test, this study conducted the test of homogeneity of regression slope within groups. If both groups are homogenous, the homogeneity assumption is not violated, suggesting that the null hypothesis is accepted. After eliminating the influence of the covariate of creative thinking ability, the one-way ANCOVA was conducted to compare if there is significant difference between both groups in the creative thinking ability post-test.

Table 5

Summary of the Independent-Sample T-Test of Creative Thinking Ability Pre-test of Both Groups

Group	The number of participants	Mean	SD	*t*-value	*p*-value
The experimental group	13	7.85	4.488	-0.938	0.357
The control group	14	9.64	5.387		

With significance level $\alpha = 0.05$, Table 6 shows the test of within-subject effects, i.e., the summary of the test of homonymy of regression coefficient within groups. The results of the test of homonymy of regression coefficient within groups (Teaching method * Creative thinking ability pre-test) are $F= 3.603$ and $p = 0.063 > 0.05$, below the significance level. Therefore, null hypotheses should be accepted and alternative hypotheses should be rejected in the statistical test. This suggests that the regression slope of both groups is identical and parallel to each other after eliminating the influence of the creative thinking ability pretest. As this complies with the assumption in the analysis of covariance—assumption of homogeneity of regression coefficients within groups, the analysis of covariance can continue.

Table 6

Test of Homogeneity of Regression Coefficients Within Groups After Eliminating the Influence of Creative Thinking Ability Pre-test of Both Groups

Regression coefficients within groups	Type III sum of squares	*F*-value	*p*-value
Teaching method	113.907	3.941	0.053
Creative thinking ability pre-test	415.169	14.366^{*}	0.000
Teaching method * Creative thinking ability pre-test	104.115	3.603	0.063

Note. $^{*}p < 0.05$.

Table 7 shows the test of creative thinking ability of both groups, i.e., the summary of the analysis of covariance. The results of the analysis of covariance are: $F = 0.447$ and $p = 0.507 > 0.05$. They suggest that after eliminating the influence of the creative thinking ability pre-test, although the processing effect of the experimental group is insignificant, its creative thinking ability (adjusted mean = 10.589) is significantly higher than that of the control group (adjusted mean = 9.560) after experiment intervention.

Differential Analysis of Creative Thinking Points

In order to discern the difference in creative thinking between both parties before the experimental teaching, this study conducted a Chi-square test. Table 8 shows the score and percentage within groups in 11 creative points of both groups, where *t*-value = 2.00 and $p = 0.157 > 0.05$. As the results are below the level of significance, there was no significant difference between both groups in creative thinking points before the experimental teaching, suggesting that the initial level of both groups is similar.

Table 7

Summary of the Analysis of Covariance Within Groups After Eliminating the Influence of Creative Thinking Ability Pre-test

Source	Type III sum of squares	Mean of sum of squares	*F*-value	*p*-value	Eta square
Corrected mode	741.721a	370.861	12.210*	0.000	741.721a
Intercept	199.409	199.409	6.565*	0.013	199.409
Creative thinking ability pre-test	736.432	736.432	24.245*	0.000	736.432
Teaching method	13.573	13.573	0.447	0.507	13.573
Error	1,549.112	30.375			1,549.112

Note. $^{*}p < 0.05$.

Table 8

Chi-square Test of Creative Thinking Point Pre-test of Each Group

Creative thinking points		The experimental group	The control group	*t*-value	*p*-value (two tail)
Material	Replacement or improvement	31 (22.96%)	34 (18.28%)	2.00	0.157
	Physical property change	8 (5.93%)	10 (5.38%)		
	Chemical property change	0 (0.00%)	0 (0.00%)		
Mechanism	Product structure	15 (11.11%)	23 (12.37%)		
	Product operation	13 (9.63%)	24 (12.90%)		
Appearance	Size	9 (6.67%)	13 (6.99%)		
	Shape	12 (8.89%)	8 (4.30%)		
	Quantity	1 (0.74%)	17 (9.14%)		
	Pattern deployment	17 (12.59%)	10 (5.38%)		
Function	Production function	20 (14.81%)	25 (13.44%)		
	New product applications	9 (6.67%)	22 (11.83%)		

Before the experimental teaching, “replacement or improvement” (The experimental group = 22.96%; the control group = 18.28%) and “product functions” (The experimental group = 14.81%; the control group = 13.44%) were the focus creative thinking points of both groups, and neither group scored in the creative thinking point “chemical property change” (The experimental group = 0.00%; the control group = 0.00%).

Table 9 shows the score and percentage within groups in 11 creative points after the experimental teaching of both groups, where *t*-value = 14.624 and $p = 0.102 > 0.05$. As the results are below the level of significance, there was no significant difference between both groups in creative thinking points after the experimental teaching.

After the experimental teaching, “replacement or improvement” (21.88%), “production function” (20.31%), and “new product applications” (19.53%) became the focus creative thinking points of the experimental group; while “production function” (24.11%), “product operation” (19.86%), and “replacement or improvement” (18.44%) became the focus creative thinking points of the control group. The experimental group received no score in “physical property change” and “chemical property change”; while the control group received no score in “chemical property change” and “shape”.

Table 9

Chi-square Test of Creative Thinking Point Post-test of Each Group

Creative thinking points		The experimental group	The control group	*t*-value	*p*-value (two tail)
Material	Replacement or improvement	28 (21.88%)	26 (18.44%)	14.624	0.102
	Physical property change	0 (0.00%)	3 (2.13%)		
	Chemical property change	0 (0.00%)	0 (0.00%)		
Mechanism	Product structure	15 (11.72%)	17 (12.06%)		
	Product operation	21 (16.41%)	28 (19.86%)		
Appearance	Size	1 (0.78%)	1 (0.71%)		
	Shape	2 (1.56%)	0 (0.00%)		
	Quantity	7 (5.47%)	4 (2.84%)		
	Pattern deployment	3 (2.34%)	4 (2.84%)		
Function	Production function	26 (20.31%)	34 (24.11%)		
	New product applications	25 (19.53%)	24 (17.02%)		

Analysis of the Results of Learning Satisfaction

The score shows the degree of learning satisfaction of students. Although the mean and standard deviation of each construct was analyzed, the results cannot judge their standard and the research will be less rigorous. As the one-sample *t*-test can find if there is significant difference and the range of level of significance, this study implemented the one-sample *t*-test to measure the learning satisfaction of students of the electronic engineering section of technical high schools receiving IBL in capstone project and their degree of response to each construct and the whole course in order to further investigate each item. Based on the five-point Likert scale, the mean of continuous variables was defined: $1 \leqq \bar{x} < 1.5$ refers to "Highly unsatisfied"; $1.5 \leqq \bar{x} < 2.5$ refers to "Unsatisfied"; $2.5 \leqq \bar{x} < 3.5$ refers to "Fair"; $3.5 \leqq \bar{x} < 4.5$ refers to "Satisfied", and $4.5 \leqq \bar{x} < 5$ refers to "Highly satisfied". This study tested with the scale value 4.5. If the *t*-test result is significant, the upper and lower bounds within the mean's range below 4.5 is called "Satisfied"; if the *t*-test result is insignificant, it is considered as the same 4.5, i.e., "Highly satisfied".

"Cognition" construct of learning satisfaction. Table 10 shows the overall mean in "cognition" of the IBL satisfaction of the experimental group is 4.64, *SD* is 0.38, and the mean of each item falls between 4.46 and 4.77. The result of the one-sample *t*-test (referenced value 4.5) is $t = 1.324$, below the level of significance, and $4.5 \leqq \bar{x} < 5$ by definition refers to "Highly satisfied". Therefore, students are highly satisfied with IBL in the cognition construct.

"Skills" construct of learning satisfaction. Table 10 shows the overall mean in "skills" of the IBL satisfaction of the experimental group is 4.35, *SD* is 0.48, and the mean of each item falls between 3.92 and 4.62. The result of the one-sample *t*-test (referenced value 4.5) is $t = -1.104$, below the level of significance, and $4.5 \leqq \bar{x} < 5$ by definition refers to "Highly satisfied". Therefore, students are highly satisfied with IBL in the skills construct.

"Affection" construct of learning satisfaction. Table 10 shows the overall mean in "affection" of the IBL satisfaction of the experimental group is 4.38, *SD* is 0.454, and the mean of each item falls between 4.08 and 4.69. The result of the one-sample *t*-test (referenced value 4.5) is $t = -0.966$, below the level of significance, and $4.5 \leqq \bar{x} < 5$ by definition refers to "Highly satisfied". Therefore, students are highly satisfied with IBL in the affection construct.

"Creativity" construct of learning satisfaction. Table 10 shows the overall mean in "creativity" of the IBL satisfaction of the experimental group is 4.61, *SD* is 0.65, and the mean of each item falls between 4.08 and 4.69. The result of the one-sample *t*-test (referenced value 4.5) is t = 0.640, below the level of significance, and $4.5 \leqq \bar{x} < 5$ by definition refers to "Highly satisfied". Therefore, students are highly satisfied with the IBL in the creativity construct.

Table 10

Mean and Standard Deviation of Learning Satisfaction with IBL of the Experimental Group

Item (Internal consistency: Reliability)	Mean	*SD*	*t*-value (based on 4.5)	Degree of satisfaction
Cognition (Cronbach α = 0.879)	4.64	0.38	1.324	Highly satisfied
2. Leaning new concepts from peers	4.77	0.42	2.214*	Highly satisfied
3. Understanding basic concepts better	4.54	0.50	0.267	Highly satisfied
4. Improving the use of professional knowledge	4.77	0.42	2.214*	Highly satisfied
5. Improving analysis and judgment abilities	4.69	0.46	1.443	Highly satisfied
6. Improving integration ability	4.62	0.49	0.822	Highly satisfied
7. Improvement learning efficacy	4.46	0.63	-0.210	Highly satisfied
Skills (Cronbach α = 0.808)	4.35	0.48	-1.104	Highly satisfied
8. Helping determine capstone project title	4.15	0.66	-1.812	Highly satisfied
9. Helping improve operating skills	4.54	0.63	0.210	Highly satisfied
10. Helping improve product functions	4.62	0.49	0.822	Highly satisfied
11. Shortening product completion time	3.92	0.73	-2.739*	Satisfied
12. Helping resolve problems	4.54	0.50	0.267	Highly satisfied
Affection (Cronbach α = 0.886)	4.38	0.454	-0.966	Highly satisfied
13. More opportunities for brainstorming	4.69	0.61	1.100	Highly satisfied
14. More for asking questions	4.31	0.61	-1.100	Highly satisfied
15. Reducing pressure from problems	4.08	0.83	-1.769	Highly satisfied
16. Boosting imagination	4.38	0.62	-0.640	Highly satisfied
17. Improving peer friendship	4.38	0.74	-0.542	Highly satisfied
18. Motivating learning	3.85	0.77	-2.944*	Satisfied
19. Wishing to use IBL in other subjects	4.15	0.66	-1.812	Highly satisfied
21. Improving communication and coordination skills	4.62	0.49	0.822	Highly satisfied
22. Enhancing peer-interaction	4.69	0.46	1.443	Highly satisfied
23. Helping sharing with peers	4.62	0.49	0.822	Highly satisfied
24. Developing teamwork spirit	4.31	0.82	-0.811	Highly satisfied
25. Enhancing interaction with teachers	4.46	0.63	-0.210	Highly satisfied
Creativity (Cronbach α = 0.804)	4.61	0.65	0.640	Highly satisfied
26. Stimulating creative ideas	4.62	0.62	0.640	Highly satisfied
27. Stimulating more new ideas	4.38	0.62	-0.640	Highly satisfied
28. Improving response flexibility	4.69	0.61	1.100	Highly satisfied
29. Enabling thinking in greater detail	4.08	0.81	-1.769	Highly satisfied
Overall (Cronbach α = 0.942)	4.50	0.387	-0.027	Highly satisfied

Discussions

From the innovative and creative teaching point of view, creative teaching is adding creative elements in the teaching process, and the method of creative teaching should be emphasized in lieu of the learning efficacy of students (Shih & Chang, 2012). This study thus focused on the effect of IBL on the inquiry ability and creative thinking ability of students. After eight weeks of experiment, this study drew the following conclusions.

Inquiry ability refers to students' ability to materialize creative ideas with their creativity. In this eight-week IBL, the course teacher administered the capstone project course with IBL in units including course overview, project conceptualization, software design for circuit making (I), hardware design for circuit making (I), software design for circuit making (II), hardware design for circuit making (II), completing circuit and functionality tests, and capstone project production and modification. Statistics on the experiment results show that after eight weeks of IBL, the inquiry ability score of the experimental group is significantly higher than that of the control group in the following five constructs: "question defining, design planning, work verification, analysis and explanation, and communication and discrimination".

The findings of this study are similar to that of Duran and Dökme (2016) who measured the difference between the experimental and control groups with IBL experimental teaching. In that study, he found that the inquiry abilities of the experimental group outperformed the control group in the formation and evaluation of alternative hypotheses and hypothesis selection, experiment design, as well as prediction and interpretation of experiment results. These results coincide with the finding of this study that IBL can improve the inquiry ability of students.

This study implemented IBL in the capstone project course of the electrical engineering section of technical high schools to guide students to discover questions in daily life, listen to different opinions, and discover the features of a diversity of events through peer-discussions. The conflict between new and old experiences will inspire more questions. By designing leading questions, teachers can stimulate the learning motivation and interests of students. With demonstration and elucidation in the teaching process, teachers can guide students to conduct the correct operations. In the practice process, students can experience and verify their respective theories. Lastly, students can submit a report and share experiment experience. In the process, students keep stimulating creative thinking and are motivated to learn competencies voluntarily.

This finding is similar to the conclusions of Hugeratm and Kortam (2014) who encourages students to find questions in daily life to improve articles of daily use through creative thinking teaching. The results of her study found that through repeated thinking, students could develop confidence and practical ability, and successfully completed the application for over 20 utility model patents. Therefore, creative thinking teacher can effectively improve the creative thinking ability of students. Salehizadeh and Noureddin (2014) indicated that IBL can significantly improve the creativity and influence the learning attitude of students, and their results coincide with the IBL experiment of this student.

Creative thinking ability refers to students' ability to materialize creative ideas with their creativity. It includes overall creativity, fluency, and creative thinking points. The statistics on the experiment results show that after eight weeks of IBL teaching, the number of creative thinking points of the experiment group in "product operation", "quantity", "product functions", and "new product applications" increased significantly, suggesting that IBL can diversify the creative thinking points of students. Among all 11 creative thinking points, the experimental group focused on four creative thinking points: "replacement or improvement", "product functions", "new product applications", and "product operation". This result shows that applying CP-IBL to the capstone project curriculum can stimulate the thinking diversity and enrich the creativity and imagination of students. Other research results also coincide with the CP-IBL experiment of this study. IBL requires students to make constant communication with others in order to significantly improve the open-mindedness, originality, elaboration, adventurousness, and imagination of students (Lou et al., 2012), and thereby, optimize creative thinking ability.

The overall satisfaction of electrical engineering students of technical high schools taking the capstone project course administered with IBL is high. By measuring learning satisfaction with the learning satisfaction inventories, this study found that those students were highly satisfied with IBL in four constructs of “cognition”, “skills”, “affection”, and “creativity”. This finding is similar to the conclusions of Salehizadeh and Noureddin (2014) who combined cooperative learning and IBL to teach engineering economics. Lourdes (2016) also found that participants could achieve the learning targets and were satisfied with IBL which enabled them to develop professional technology, improve team cooperation, and build confidence in future expertise. In Al Musawi, Asan, Abdelraheem, and Osman’s (2012) study showed that a well-designed learning environment can enhance students learning experience. These results also coincide with the finding of this study that IBL can significantly enhance the learning efficacy and improve the learning attitude of students.

Capstone projects have already been adopted by many local and foreign educational systems, and several scholars have explored theories of project learning and developed teaching models for capstone project course (Chang, 2017; Fernandes, Mesquita, Flores, & Lima, 2014; Kokotsaki, Menzies, & Wiggins, 2016; Ljung-Djärf, Magnusson, & Peterson, 2014; Wolk, 1994). For example, Shyu Hsin-yih (2001) proposed five steps of implementation (abbreviated as PIPER) in his research for capstone project:

1. Preparation: verify the scope of topic, determine the teaching objective, confirm the schedule of progress and method of evaluation, confirm resources, and verify prior knowledge, organization/team, and instructor training;

2. Implementation: arrange and define the division of labor and responsibilities, brainstorming, formulate the plan for projects, propose hypotheses, collect relevant data, analyze, and authenticate relevant data, team collaboration, progress report, and integration of results from analyses and propose conclusion;

3. Presentation: present and share the conclusions and findings from the study (in the format of a written report and oral presentation);

4. Evaluation: assessment of project-based learning results with self-evaluation, peer-evaluation, and expert evaluation;

5. Revision: revise the project based on the results of evaluation to finalize the project and complete the learning process for the project (Shyu, 2001).

For the observation what happened among students of experimental group during the instruction of this study, Shyu’s five stages of capstone project learning implementation include: preparatory stage (P), implementation stage (I), presentation stage (P), evaluation stage (E), and revision stage (R) shed light on the teaching process for instructors.

To cover the instruction aims, the Shyu’s five stages were compared, analyzing the design circuits of multiple function package produced by the participants in the capstone project course and also the observations from the course. Table 11 provides a summary of the stages of changes found from observation. There were many changes that happened with students. For example, one student reflected all the relevant procedures from the initiation of their ideas to their implementation during the presentation stage.

Table 11

Summary of Changes on Students From Observation

Stage	Instructional action	Activities of student	Changes happened on students by observation
Preparatory	Foster collaboration from the start (team building); Encourage collaboration by sharing information; Shared reflection on sustainability values; Building community by “LINE” which is communication software; Communicate and discuss results.	Students need to go through preparations of professional skills and knowledge.	Concreteness of the formulation of competencies and expression of specific learning activities.
Implementation	Inclusion of collaborative activities in the course; Icebreaker activity. Decide working tools together; Clarify the use of LINE and introduce it from the beginning; Initial debate for motivation; Create resource information repository Create a space for group; interchange/reflection; Shared repository in drive: Improve its utility by classifying the references by fields and labeling the information resources; Introduce Google Scholar to seek more sound information; Initial debate before definitive conclusions.	Instructors are required to guide their students through extensive data collection and resource acquisition before students divide their responsibilities in teams and collaborate to complete their projects.	Concreteness of spaces for socializing, interchange, and shared reflection; Organization and scheduling.
Presentation	Introduce a digital SWOT tool; List possible sustainability problems and work problems; Informal exchange space for students.	Students are required to make adequate use of their capacity for expression and communication to present the results of their projects.	Resources selection; Communicate with others; Reflection all the procedure from ideas initiate to implementation.
Evaluation	Reinforce the support between peers and teacher feedback; Peer-assessment; Share information resources among students; Foster teachers’ participation; Teaching feedback more personalized and in different formats (audio, text, and video); More direct channel of communication with the teacher to renegotiate assessment criteria; Audiovisual presentation of the IBL process; Illustrate the working process and products; Introduce social support elements creating a supportive community.	Students’ projects would be subjected for evaluation by their instructors, experts from the industry and peers to inspire different creative thinking.	Delimit ways of participation/support among students in learning activities and assessment; Students are promoted by specify teacher’s support; Increase and improve the teaching feedback from student’s performance.
Revision	Concreteness of outcomes; Attending competitions; Collect good ideas; Delimit and better redefine the type of final product; Patents contributions.	Instructors would guide students through the process of revision for the finalized project based on various suggestions before students are officially entered into competitions and patent application to complete their practical project courses.	Improvement, delimitation, and definition of the final product.

Conclusions and Recommendations

Based on the research findings, this study can make the following conclusions and recommendations for the reference of teachers teaching with IBL, school administration units, and future researchers.

Based on this study’s findings, in order to improve the creative thinking ability, inquiry ability, and learning satisfaction of electrical engineering students of technical high schools, teachers must become familiar with IBL application to understand the learning efficacy of IBL. In addition, in the learning satisfaction survey, this study found that the mean score of learning motivation maintenance is the lowest among all items. Therefore, there is still space for teaching adjustments to teachers. The following teaching recommendations are made concerning the IBL implementation process:

The literature review and research results show that the role of teachers is a key to success in IBL. IBL is a teaching method based on the inquiry activity of students. It aims to guide students to discover and resolve problems. By guiding students to find problem solutions in the teaching process can inspire the creative thinking ability and inquiry ability of students. The teachers who often are also the course designers must be knowledgeable and efficient to manage and deliver suitable course materials. Without sufficient knowledge and support, parties, the teachers, and the students, could easily become technophobic and frustrated when making their designs (Mohamad, Hussin, & Shaharuddin, 2015).

One-way knowledge and skill instruction of teachers and one-sided memorization and recitation of students are the main differences between traditional didactic teaching and IBL. By contrast, IBL uses daily life and interesting content to engage students and make them feel curious about learning. Linking teaching with daily life can stimulate learning interests and enables students to understand the meaning of learning in order to discover, explore, and resolve problems with the knowledge acquired.

In our study, besides changes happened on students, the teacher participated in experimental teaching was not struggle with managing classroom inquiry activities anymore, and he also wants to use IBL again next year, because students will be able to manage their own time effectively during an inquiry lesson. IBL is a student-centered teaching method. In this method, teachers are facilitators and helpers, students learn either individually or in groups, and teachers adjusts the progress based on the learning situation of students. Students are allowed and encouraged to explore and experiment to come up with their own conclusions about scientific concepts (Kilinç, 2007). Technological and vocational education is established to cultivate fundamental technological talents for the industry. Teachers can stimulate students to keep thinking and exploring interesting topics with related issues in daily life or in the industry, i.e., experience learning, so that they can proactively engage in clarifying and defining questions and make hypotheses. In the learning process, students must maintain high levels of motivation to learn and make progress in order to enhance the learning efficacy of professional competencies (Litzinger, Lattuca, Hadgraft, & Newstetter, 2011). In Al Musawi et al.'s (2012) research showed that learning through inquiry will increase students' ability to apply what they learn to new situations. For professional technical courses, teachers can use multiple teaching methods for students to strengthen the construction and comprehension of professional skills through practical learning, such as observation, imitation, practice, correction, and re-creation.

Teachers can apply multiple evaluations to balance conclusive evaluation and procedural evaluation. Apart from understand the ability change of students in different aspects; teachers can observe the creativity students from their works. The practical process may involve the practice of hardware or software operating procedures or the completion of a work. Through individual or group presentations and the questions of students in other groups, students can practice verbal expression, logical thinking, and defense abilities. With encouragement and positive reinforcement, teachers can help students build confidence and enhance self-assurance.

Curricula, teaching materials, and teaching methods are three connected parts. Teachers can design teaching topics related to daily life issues, plan creative capstone project courses and teaching, and stimulate student thinking with flexible instructional design. For example, interdisciplinary teaching planning (such as integrated teaching and main unit teaching) can diversify the vision of learners. Adding IBL, brainstorming, and cooperative learning in teaching, teaching materials, and teaching methods give students the appropriate amount of determination to explore (Chen, 2015) is the only way to train the creative thinking in students and turn that into applications with greater flexibility to cope with the needs of actual situations. In addition, encouraging students to participate in off-campus creativity competitions or organizing creativity workshops to provide opportunities for using knowledge in daily life can improve the creative performance of students.

Based on the research conclusions, this study makes the following recommendations for school administration units to effectively improve the creative thinking ability and inquiry ability and enhance the learning satisfaction of electrical engineering students of technical high schools.

According to the course teachers participating in the experimental teaching of this study, IBL-related technology methods were not taught when they were students. Schools should thus encourage or help teachers participate in professional teaching communities of creative, inquiry learning in order to improve the teaching techniques and professional competencies of creative teaching of teachers through training and sharing teaching experience and learning efficacy.

According to the course, teachers participating in the experimental teaching of this study, schools have very few online forums for teachers to discuss the learning status of the students. Therefore, schools are recommended to build an IBL resources platform for teachers interested in and willing to use IBL to build an IBL team and share class management, teaching materials, and teaching methods over the platform, in order to demonstrate the effect of resource sharing and reduce the burden in teaching preparations of teachers.

Innovative and creative talents are important human resources for the country. Schools should plan budgets to purchase software and hardware equipment and facilities for creative teaching of students to encourage brainstorming and demonstrate their creativity at any time. To encourage and enforce IBL, teachers engaging in IBL should be rewarded or subsidized. Schools may also organize IBL-related forums, lesson plan competitions, and student creative thinking competitions.

This study was conducted with electrical engineering students of technical high schools. Future research may try other fields or extend the scope of research to universities of technology in order to find if IBL can improve the inquiry ability and creative thinking ability of students in these fields or establishments and to analyze the difference among different disciplines. In addition, as this study was conducted by means of quantitative research, researchers may apply qualitative research to investigate the inquiry ability and creative thinking ability of students to analyze the deep cognition process of students by adding the analysis of the contents of teacher-student interview, in order to understand the creative thinking of students in greater detail.

Implications

Theoretical Implications

This study has several important theoretical implications. First, this study enriches the knowledge of IBL by proposing capstone project IBL (CP-IBL) as a seven-step practical concept, including engagement, question, design, discussion, production, evaluation, and revision. This study extends Pedaste et al. (2015) who reviewed the 32 articles that resulted in the identification of five distinct general inquiry phases: orientation, conceptualization, investigation, conclusion, and discussion. The study also applied Shyu (2001), who had developed five stages of project-based learning implementation include: preparation, implementation, presentation, evaluation, and revision for instruction; and extends the work of Bybee et al. (2006), who established 5E learning cycle model as lists five inquiry phases: engagement, exploration, explanation, elaboration, and evaluation by arguing that IBL extended a seven-step practical concept and developed a CP-IBL.

Second, this study highlights the importance of practical-problem-solving in IBL. In previous works, the setting of IBL aspires to engage students in an authentic scientific discovery process (Suárez et al., 2018). From a pedagogical perspective, the complex scientific process is divided into smaller, logically connected units that guide students and draw attention to important features of scientific thinking (Pedaste et al., 2015). However, this traditional purpose of inquiry learning limits potential to explore the participation of practical-problem-solving or hands-on opportunity in experiencing capstone project. A clear understanding of capstone project requires a product of the role of hands-on in the experience of practical-problem-solving, especially when emphasizing practice experiences delivered by finishing product during a capstone project course (Fernandes et al., 2014). Both scientific thinking and practical problem solving are learning behaviors that could be experienced through team members interactions at practice workshop in technical high schools.

Practical Implications

This study also has valuable practical implications. First, the teaching model in this study provides capstone projects that have complete and systematic instruction of IBL. Although several IBL emphasize “problem-solving” in science education, the literature has not defined or clearly explained related problems. Previous works done by educational psychologists in the scientific education (e.g., Fernandez et al., 2014; Figueroa, 2016; Pedaste & Sarapuu, 2006) have not convinced IBL under different problem types to apply the concept of solving the real life or industrial problems directly in capstone project. Through the established teaching procedure and method in this study, capstone project could now gain clear information about the content of IBL in technical high school. Thus, teachers not only confident with managing practice workshop inquiry activities, they also are concerned that students will be able to manage their own time effectively during a capstone project course.

Second, teachers can not only serve as a guide during the CP-IBL, but also cooperate with industries related to the technical high school. Through the incorporation of field experience from the relevant industries, teachers will be able to further boost their professional knowledge. With regards to brainstorming for potential topics for capstone projects, teachers should attempt to guide students to have a personal appreciation for the topic through relevant elements in their daily life to stimulate their motivation for learning and use the capstone as a means to take students beyond the confines of their schools into the real market (i.e., communities, stores, and so forth). This allows students to see for themselves and discover the market demand before they apply the knowledge they have learned to resolve the problem in the market. This would help students to train their capacity to identify opportunities, inquiry, and problem-solving abilities.

Third, the products of capstone project course can be used in taking part competition to emphasize how effect student’s life is. After helping their students to complete and revise their projects for their presentation, teachers from electrical engineering departments in technical high school would actively encourage their students to take part in various competitions outside of their schools (mostly events hosted by the Ministry of Education and relevant companies in the sector). Taking part in competitions organized by the Ministry of Education and achieving a good performance would help students in their future academic careers, while helping students to compete and win in events hosted by corporations would help the corporations to take note of students' talents and help the students become connected to the businesses to close the gap between their learning and application of skills. Furthermore, as for the students, due to their involvement in the capstone project courses, they would receive invaluable practical and learning experiences from the process of their participation and perhaps discover their interests and continue to work hard in relevant fields while pursuing their different goals of completing their education, seeking employment, or starting their own businesses to truly attain the greatest benefit of capstone project courses.

Limitations

As Taiwan's new birthrate is quite low and the number of universities is still quite large, many middle school students have chosen to attend high school. Therefore, in technical high schools, the average number of students in a class has dropped to 15-20. The number of subjects (13 in the experimental group while 14 in the control group) may be too small a sampling. For approaching the real effect by the experimental teaching, the research objects used in this study are randomly assigned students in existing technical high school classes.

References

Al Musawi, A., Asan, A., Abdelraheem, A., & Osman, M. (2012). A case of web-based inquiry learning model using learning objects. *The Turkish Online Journal of Educational Technology, 11*(1), 1-9.

Alfieri, L., Brooks, P. J., Aldrich, N. J., & Tenenbaum, H. R. (2011). Does discovery-based instruction enhance learning? *Journal of Educational Psychology, 103*, 1-18. doi: 10.1037/a0021017

Anastopoulou, S., Sharples, M., Ainsworth, S., Crook, C., O'Malley, C., & Wright, M. (2012). Creating personal meaning through technology-supported science inquiry learning across formal and informal settings. *International Journal of Science Education*, *34*(2), 251-273.

Andreassen, T. W. (2001, August). From disgust to delight: Do customers hold a grudge. *Journal of Service Research, 4*(1), 39-49.

Ausubel, D. P. (1964). Some psychological and educational limitations of learning by discovery. *The Arithmetic Teacher, 11*(5), 290-302.

Bahri, N. A. S., Azli, N. A., & Samah, N. A. (2014). An exploratory study: Problem solving process in a problem/project-based laboratory (PBLab) course. In *Proceedings of 2014 International Conference on Teaching and Learning in Computing and Engineering (LaTiCE 2014)* (pp. 226-233), Kuching, Malaysia.

Buchanan, S., Harlan, M. A., Bruce, C., & Edwards, S. (2016). Inquiry based learning models, information literacy, and student engagement: A literature review. *School Libraries Worldwide*, *22*(2), 23-40.

Buck Institute of Education (BIE). (2014). *Why project based learning*? Retrieved from http://bie.org/about/why_pbl

Bybee, R. W., Taylor, J. A., Gardner A., Scotter, P. V., Powell, J. C., Westbrook, A., & Landes, N. (2006). *The basic 5e instructional model: Origins and effectiveness* (pp. 1-80). Office of Science Education National Institutes of Health.

Cardozo, R. (1965). An experimental study of customer effort, expectation, and satisfaction. *Journal of Marketing Research, 2*(3), 244-249.

Chang, J. C. (2017). The innovative instruction for engineering and design curriculum: Innovative products embedded teaching methods for senior project. MOST Project Reports (No: MOST 103-2511-S-027-004-MY3) (Unpublished Report).

Chang, J. C., & Chou, C. F. (2018). An analysis on the teaching process of capstone courses of National Colleges' Practical Project Competition as an example. *In Proceedings of 2018 IIER 417th International Conference on Social Science and Economics* (ICSSE) (pp. 11-17), Chicago, USA.

Chang, S. H. (2011). An exploration of teaching for creativity, learning and assessment. *Bimonthly Journal of Educational Data and Research, 100*, 1-22.

Chang, Y. H., Wang, M. N., & Hsu, H. C., & Yi, C. C. (2018). *89S51 Illustrated—C language* (6th ed.). Taipei, Taiwan: HsinWenGin.

Chen, C. C. (1998). Relationship between discovery and learning: Piaget *vs.* Vygotsky. *Kid Sky, 15*, 185-203.

Chen, H. J. (2015). Key to capturing knowledge: Developing critical thinking with inquiry-based learning. *Elementary Education, 55*(1), 53-60.

Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic reasoning in schools: A theoretical framework for evaluating inquiry tasks. *Science Education*, *86*(2), 175-218.

Chou, Y. T., & Chang, J. Y. (2012). Effect of inquiry-based creative experimental teaching on the performance in the science field of eighth graders. *Tze-Chi University Journal of the Educational Research*, *8*, 53-90.

DiBiase, W., & McDonald, J. R. (2015). Science teacher attitudes toward inquiry-based teaching and learning. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *88*(2), 29-38.

Duran, M., & Dökme, İ. (2016). The effect of the inquiry-based learning approach on student's critical-thinking skills. *Eurasia Journal of Mathematics, Science & Technology Education, 12*(12), 2887-2908.

Ernst, J. V., Segedin, L. J., Clark, A. C., & DeLuca, V. W. (2014, June 15-18). Technology, engineering, and design educator professional development system implementation: Initial pilot results. In Paper was presented on the *2014 ASEE Annual Conference*, Indianapolis, IN.

Fall Creek High School. (2018). *Senior capstone project student guide*. Retrieved from http://www.fallcreek.k12.wi.us/students/Fall%20Creek%20Senior%20Capstone.pdf

Figueroa, M. (2016). Designing effective solutions for senior capstone projects. *Technology and Engineering Teacher, 10*, 1-5. Retrieve from https://www.iteea.org/ File.aspx?id=99489&v=23d8a255

Fernandes, S., Mesquita, D., Flores, M. A., & Lima, R. M. (2014). Engaging students in learning: Findings from a study of project-led education. *European Journal of Engineering Education*, *39*, 55-67.

Fortus, D., Dershimer, R. C., Krajcik, J., Marx, R. W., & Mamlok-Naaman, R. (2004). Design-based science and student learning. *Journal of Research in Science Teaching*, *41*(10), 1081-1110.

Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. C. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching. *Review of Educational Research*, *82*, 300-329. doi: 10.3102/0034654312457206

Hill Regional Career Magnet High School. (2017). *Capstone project manual 2018-2019*. Retrieved from https://www.careerhighschool.org/uploads/1/5/9/7/15971030/ capstone_manual_2017-2018.pdf

Hsiao, H. S., Chang, C. S., Lin, C. Y., & Wang, Y. Z. (2016). Weather observers: A manipulative augmented reality system for weather simulations at home, in the classroom, and at a museum. *Interactive Learning Environments*, *24*(1), 205-223. http://doi.org/10.1080/10494820.2013.834829

Huang, W. C. (2015). Impact of creative inquiry teaching on inquiry, creativity and learning outcome of students: Department of Horticulture, Song-Shan High School of Agriculture & Industry in Taipei (Unpublished doctoral dissertation, National Taiwan Normal University, Taipei, Taiwan).

Hugeratm, M., & Kortam, N. (2014). Improving higher order thinking skills among freshmen by teaching science through inquiry. *EURASIA Journal of Mathematics, Science, Technology, and Engineering Education*, *10*(5), 447-454.

Independent High School (2018). *Senior capstone project overview and details-Spring 2018*. Retrieved from http://www.independence.k12.oh.us/Downloads/Senior% 20Capstone %20Project%202018%20FINAL%20COPY%20.pdf

Industrial Technology Research Institute. (December 22, 2014). *Review and prospect of Taiwan's electronics industry*. Retrieved from https://www.itri.org.tw/chi/Content/NewsLetter/Contents.aspx?SiteID=1&MmmID=5000&MSid=6213025135301 61363

Jarvis, P. (2004). *The theory and practice of teaching*. England, London: Routledge.

Jhong, J. P. (2010). Guided model-based inquiry and modeling teaching framework. *Science Education Monthly, 328*, 2-18.

Jiang, H. C. (2014). *89S51 Express—Happy entry*. Taipei, Taiwan: HsinWenGin.

Kilinç, A. (2007). The opinions of Turkish high school pupils on inquiry based laboratory activities. *The Turkish Online Journal of Educational Technology, 6*(4), 56-71.

Knight, P. T. (2002). Summative assessment in higher education: Practices in disarray. *Studies in Higher Education*, *27*(3), 275-286.

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, *19*(3), 267-277.

Lee, S. H. (2000). *Inquiry-based learning*. Retrieved fromhttp://terms.naer.edu.tw/detail/1309716/

Lin, B. S. (1989). *Teaching principles*. Taipei, Taiwan: Wu-nan.

Lin, W. W. (2011). Creative teaching and creativity cultivation: The case of design thinking. *Educational Resources and Research, 100*, 53-74.

Lin, X. T., & Wang, M. R. (1994). *Creativity assessment packet*. Taipei: Psychological Publishing.

Litzinger, T., Lattuca, L., Hadgraft, R., & Newstetter, W. (2011). Engineering education and the development of expertise. *Journal of Engineering Education, 100*(1), 123-150.

Liu, C. H., Tang, Y. S., Chang, C. C., Chang, Y. H., & Won, S. J. (2003). Revelation of industry-academia collaboration across the world. *Technological and Vocational Education Bimonthly, 77*, 16-19.

Ljung-Djärf, A., Magnusson, A., & Peterson, S. (2014). From doing to learning: Changed focus during a preschool learning study project on organic decomposition. *International Journal of Science Education, 36*, 659-676.

Lou, S. J., Chung, C. C., Dzan, W. Y., & Shih, R. C. (2012). Construction of a creative instructional design model using blended, project-based learning for college students. *Creative Education, 3*(7), 1281-1290.

Lourdes, V. G. (2016). Inquiry-based learning in pre-service training for secondary education counselors. *Procedia-Social and Behavioral Sciences, 217*, 65-73.

Ministry of Education. (2009). *Education in Taiwan 2010-2011*. Taipei: Taiwan.

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction—What is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching, 47*, 474-496. doi:10.1002/tea.20347

Mohamad, M., Hussin, H., & Shaharuddin, S. (2015). Adult learners' perceptions of designed hypermedia in a blended learning course at public university in Malaysia. *The Turkish Online Journal of Educational Technology, 14*(1), 31-38.

Moon-Soo, K. (2017). Multidisciplinary team index in capstone course of higher education. *Advanced Science Letters*, *23*(3), 2038-2042. doi: https://libsearch.ntut.edu.tw:2600/10.1166/asl.2017.8586

Núñez, J. L., & León, J. (2015). Autonomy support in the classroom. *European Psychologist*, *20*(4), 275-283.

Oliver, R. L. (1999). Whence consumer loyalty? *Journal of Marketing, 63*, 33-44.

Pedaste, M., & Sarapuu, T. (2006). Developing an effective support system for inquiry learning in a Web-based environment. *Journal of Computer Assisted Learning*, *22*(1), 47-62.

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., Riesen, A. N. S., Kamp, van E. T., …, & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review, 14*, 47-61.

Ravitz, J., Mergendoller, J., Markham, T., Thorsen, C., Rice, K., Snelson, C., & Reberry, S. (2004, October). Online professional development for project-based learning: pathway to systematic improvement. In Paper presented at *Meetings of the Association for Educational Communications and Technology,* Chicago, IL.

Salehizadeh, M. R., & Noureddin, B. A. (2014). Effects of cooperative learning plus inquiry method on student learning and attitudes: a comparative study for engineering economic classrooms. *European Journal of Engineering Education, 39*(2), 188-200.

Shan, W. J. (2016). Critical analysis of J. Dewey's thoughts on good teachers and the preservice teacher education program. *Journal of Research in Education Sciences, 61*(2), 1-28.

Shih, J. W., & Chang, S. C. (2012). Learning efficacy of innovative and creative plans: A mission-focus perspective. *Chinese Journal of Science Education*, *20*(5), 461-482.

Shyu, H. Y. (2001). How to help children become research experts by the internet-web project-based learning and teaching innovation. *Taiwan Education Review, 607*, 25-34.

Small, T. (2009). Assessing enquiry-based learning: Developing objective criteria from personal knowledge. *The Curriculum Journal, 20*(3), 253-270.

Smith, A. K., & Bolton, R. N. (1998). An experimental investigation of customer reactions to service failure and recovery encounters: Paradox or peril?. *Journal of Service Research, 1*(August), 65-81.

Steinlicht, C., & Garry, B. G. (2014). Capstone project challenges: How industry sponsored projects offer new learning experiences. In *Proceedings of the ASEE Annual Conference and Exposition* (p. 11), Indianapolis, IN.

Suárez, A., Specht, M., Prinsen, F., Kalz, M., & Ternier, S. (2018). A review of the types of mobile activities in mobile inquiry-based learning. *Computer and Education*, *118*, 38-55.

Suarez, A., Ternier, S., Kalz, M., & Specht, M. (2015). Supporting inquiry-based learning with Google glass (GPIM). *Interaction Design and Architecture(s) Journal—Ix D&A*, *24*, 100-110.

Thomas, J. (2000). *A review of research on project-based learning*. San Rafael, CA: Autodesk Foundation. Retrieved from http://www.bie.org/images/uploads/general/ 9d06758fd346969cb63653d00dca55c0.pdf

Tseng, Y. J. (2015). Creative thinking for the cluster of electrical and electronics engineering students of vocational high school in technical project contest (Unpublished master's thesis, National Taipei University of Science and Technology, Taipei, Taiwan).

Turner, W., & Pidcock, M. (2006). Using oral presentations of project work to improve communication skills. *International Journal of Mathematical Education in Science and Technology*, *20*(6), 879-883. doi: 10.1080/0020739890200611

Williams, F. E. (1972). *Encouraging creative potential*. New Jersey, NJ: Educational Technology Publications.

Wolk, S. (1994). Project-based learning: Pursuits with a purpose. *Educational Leadership*, *52*(3), 42-45.

Woodstock High School. (2015). *Senior capstone career project Woodstock 2016-2017*. Retrieved from http://cherokeek12.net/woodstockhs/wp-content/uploads/sites/10/ 2016/10/Senior-Capstone-Career-Project-handbook.pdf

Wu, L. C., & Lyau, N. M. (2010). Evaluation module construction for capstone project of the commercial field of senior high vocational schools. *Quarterly Journal of Commercial Vocational Education, 119*, 48-54.

Wu, Y. C., Hsieh, L. F., & Lu, J. J. (2015). What's the relationship between learning satisfaction and continuing learning intention? *Procedia Social and Behavioral Sciences, 191*, 2849-2854.

Yang, Y. F. (2016). The influence on students' creative thinking and inquiry ability with inquiry-based teaching in capstone project in the department of the electrical engineering at vocational-technical senior high school (Unpublished master's thesis, National Taipei University of Science and Technology, Taipei, Taiwan).

Yen, H. C. (2004). View inquiry teaching from constructivism perspective. *Research and Development in Science Education Quarterly, 36*, 1-14.

Zhou, Y. T., & Chang, J. Y. (2012). Effect of inquiry-based creative experimental teaching on the performance in the science field of eighth graders. *Tze-Chi University Journal of the Educational Research, 8*, 53-90.