PROJECT-BASED LEARNING WITH AN ONLINE PEER ASSESSMENT SYSTEM IN A PHOTONICS INSTRUCTION FOR ENHANCING LED DESIGN SKILLS

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ABSTRACT
This study proposed a novel instructional approach, a two-stage LED simulation of Project-based learning (PBL) course with online peer assessment (OPA), and explored how to apply OPA to the different structured problems in a PBL course to enhance students' professional skills in LED design as well as meta-cognitive thinking. The participants of the study, 73 junior students were divided into two groups, OPA group (with OPA) and Traditional group (without OPA). The evaluation results were listed as follows. (1) OPA group performed better than Traditional group in concept clarification. (2) For the enhancement of LED design skills in well-structured problem solving, OPA group performed better than Traditional group. (3) For the enhancement of LED design skills in ill-structured problem solving, there was no significant difference between the performances of these two groups. (4) For students' perception about the effect of OPA applied in PBL, OPA group could benefit from inquiry learning and reflective thinking. Most students agreed that the two-stage LED simulation of PBL course was challenging and interesting and they learned useful things from the course.
Keywords: Cooperative/collaborative learning, interdisciplinary projects, improving classroom teaching.

INTRODUCTION

The application scope of LED devices has widened recently. Taiwan has gained the second largest market share in the global LED market since 2002 and its market size for LEDs will be NT$540 billion in 2015 (Huang, 2009). Efficiently fostering LED device design professionals has become an issue in higher education to meet the growing demand for the engineers in Taiwan's LED industry. For a student in higher education to successfully completing a LED design requires prior knowledge of semiconductor physics, quantum mechanics, optoelectronics, and material science. Universities need to offer an interdisciplinary curriculum that combines theory and practice to engage students in authentic real-world tasks and to develop their skills in problem solving (Macías-Guarasa, Montero, San-Segundo, Araujo, & Nieto-Taladriz, 2006).

Project-based learning (PBL), a student-centered teaching approach, enables students to integrate their knowledge, skills, values, and attitudes and to construct knowledge through a variety of learning experiences (Maskell & Grabau, 1998). Students deal with interdisciplinary issues as well as pursue solutions to a problem by asking and refining questions, debating ideas, making predictions, collecting and analyzing data, drawing conclusions, and communicating their findings to others (Macías-Guarasa et al., 2006). Moreover, with the assistant of computer simulation technology, the strength of PBL has been highly enhanced for the decades. Simulation-assisted learning (SAL) can help students understand the real world, be able to explore and test hypotheses, and come to a reasoned explanation of the phenomenon in question (Lunette and Hofstein, 1991; Stern et al., 2006). Furthermore, the time and cost required for the development of the products can be markedly reduced by the elimination of unnecessary trial fabrications (Yaeger et al., 2004; Chang, Chen, Kuo, & Shen, 2011). Nevertheless, some studies have revealed that the simulation itself cannot provide an abundant learning environment and that one-on-one simulation-based instruction cannot enrich knowledge acquisition (Rieber & Parmley, 1995).

Peer assessment recently has often been applied as an alternative assessment method in many different fields, (Strachan & Wilcox, 1996; Falchikov & Goldfinch, 2000). In the process of peer assessment, students are able to evaluate and learn from peers' work and comments, then work with self-comparison; discover the shortcomings of their own work, and determine the right way to improve their works (Topping, 1998; McGourty, 2000). Thus, the process enhances students' meta-cognitive understanding about their own learning process (Wen & Tsai, 2006; Liu & Lin, 2007); and develops their social and transferable skills (Topping, 1998), and helps them to clarify their misconceptions.

With the vigorous development of information networks, online peer assessment (OPA) has been a success, which provides a more comfortable learning environment that is free from geographic and time constraints. It also allows participants to work and be graded anonymously (Davies, 2000; Lin, Liu, & Yuan, 2001; Liu, Lin, Chiu, & Yuan, 2001; Tsai, Liu, Lin, & Yuan, 2001; Freeman & McKenzie, 2002; Liu & Lin, 2007; Shih, 2011). Many studies have focused on the factors that affect the performance of OPA, including the number of OPAs (Tsai et al., 2001), students' perception and attitudes about PA and OPA (Wen & Tsai, 2006), teachers' perception about PA (Wen, Tsai, & Chang, 2006), provision of prerequisite instruction and training of OPA for students before conducting OPA (Orsmond & Merry, 1996), and PA in a Web-based portfolio assessment environment (Chang, Tseng, & Lou, 2011).

As for the literature of students' perception and attitudes about OPA, Wen & Tsai (2006) developed an instrument to examine university students' opinions toward OPA. Four subscales, Positive Attitudes, Online Attitudes, Understanding-and-Action, and Negative Attitudes, were extracted. Results revealed that participating students held positive attitudes toward the use of PA activities, but they viewed OPA as a technical tool to facilitate assessment processes, rather than as a learning aid. Moreover, most of the students suggested that the PA score should be counted as a small part of the total course grade, and there was an effect of the perceived importance of PA score on students' attitudes toward these four subscales.

However, few literature deals with how OPA works in different structured problems in a PBL course and students' perception about the effect of OPA applied in PBL, which could be an important guidance for teachers to successfully implement OPA in PBL. This study proposed a novel instructional approach, a two-stage LED simulation of PBL course with OPA to enhance students' learning performance in LED design. Moreover, the study explored how to apply OPA according to the structured level of a problem in a PBL course to enhance students' meta- cognitive thinking. Knowledge maps, a photonics scoreboard, and the Constructivist Project-based Learning Environment Survey (CPLES) (Chang, 2006), quantitative research approach, were conducted to demonstrate the effects of this learning course. Furthermore, an in-depth-interview, a qualitative research approach, was used to gather an in-depth understanding of students' behavior and the reasons that govern such behavior. The study addressed the following research issues. (1) The effect of OPA upon concept clarification. (2) The effect of OPA upon enhancing LED design skills in structured problem solving. (3) The effect of OPA upon enhancing LED design skills in ill-structured problem solving. (4) Students' perception about the effect of OPA applied in PBL.

Two-stage LED simulation of PBL course with OPA

According to the theories of constructivism (Honebein, 1996; Wilson, 1996; Tsai, 1998; 2000) and cognitive load (Sweller, Van-Merrienboer, & Paas, 1998), the two-stage LED simulation of PBL course with OPA was developed to enhance students' professional skills in LED design as well as meta-cognitive thinking (Chang, Chen, Kuo, & Shen, 2011). The computer simulation software, APSYS, developed by the Crosslight Software Inc., Canada, was adopted in the PBL course. To achieve the above objectives, the LED simulation of PBL course was divided into two stages. The first stage aims to help students learn the operation of APSYS and realize the concept of the active region and how parameters influence an LED. Thus, the project at the first stage was developed as a well-structured problem which was easier for students to solve. The goal of the second stage was to help students realize that several parameter settings could achieve the development goal for the given wavelength, current, and power. Students should find an optimal solution among these parameter settings. The project at the second stage was developed as an ill-structured problem which provided more challenge for students to overcome.

Fig. 1 shows the LED simulation of PBL with OPA. First, the instructor assigned a project to all the teams. Second, the students discussed this between themselves and researched information online and in textbooks or technical journals to form their initial ideas. Third, students performed simulations to clarify their concepts. In this step, the teammates were expected to produce a solution to their set project following the simulation. In the fourth step, students checked if their solutions met the aim of the project. Students who had met the objective at this stage finished the simulation. Students who had not achieved the project goal were required to repeat steps 3–5. Repeating steps 3–5 helps students to build their concepts of the operating principle of LEDs. In the sixth step, all teams compared their results when they had achieved the objective. The team online PA step enabled the students to examine each others' results to understand how to gain better results by using different parameters.

The structure of a blue LED used in this study is shown in Fig. 2. In the first stage, students were asked to adjust the InGaN well layer, the Shockley–Read–Hall (SRH) lifetime, and the internal loss in order to learn how these parameters influence the performance of the LED. For instance, increasing the indium (In) composition in the InGaN well layer lengthens the wavelength; decreasing the thickness of the InGaN well layer shortens the wavelength; reducing the internal loss can raise the output power and internal quantum efficiency.

Two objectives were included in the second simulation stage. The first was to design an LED with a wavelength of 460 nm, an injection current of 30 mA, and an output power of 1.5 mW, according to the study of Oder et al. (2004). The other objective was to design an LED with a wavelength of 476 nm, an injection current of 35 mA, and an output power of 1 mW, after the paper of Choi et al. (2003). In this stage, students attempted to reach the given targets based on the concepts that were established in the first stage.

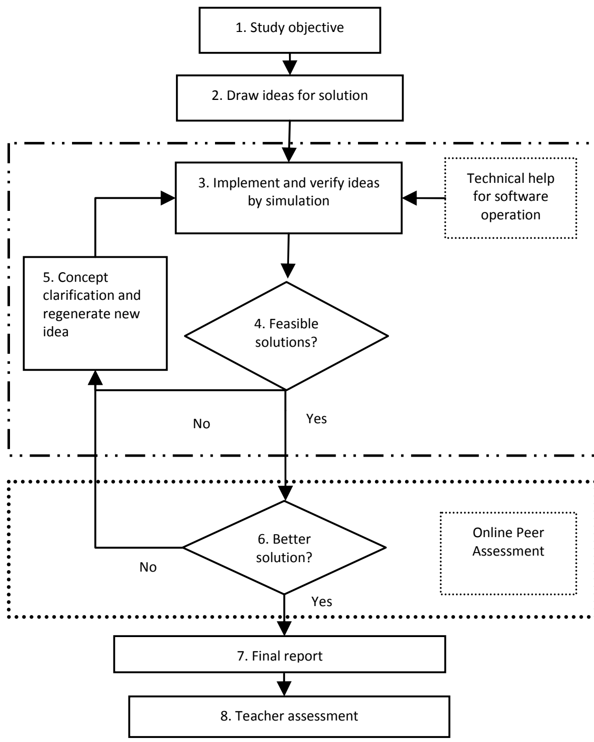

Fig. 1. Process of simulation-based learning with online peer assessment.

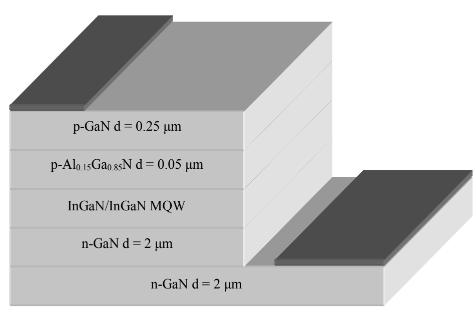

Fig. 2. Structure of the blue LED under study.

Online peer assessment

In the OPA system, there were two kinds of identities: teacher (administrator) and student. Fig. 3 showed the OPA system provided teacher with the mechanisms to control and manage OPA process. The functions of OPA system were to upload students' homework, assess each other, and provide suggestions about others' projects. The study conducted OPA three times. Only the last two scores were adopted as the evaluation, since the first one was given to students as the OPA training to ensure its feasibility.

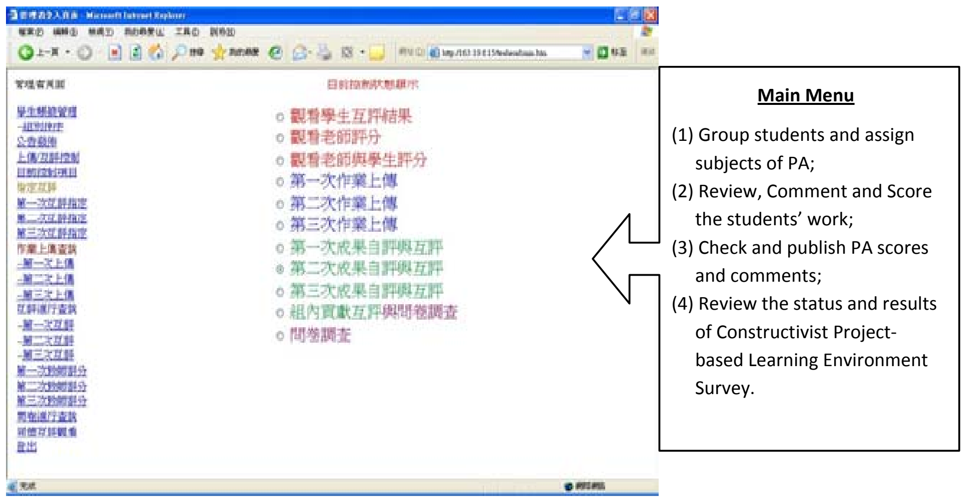

Fig. 3. Administrator control interface of OPA.

RESEARCH METHODOLOGY

Participants

The participants of the study were 73 junior students of two classes, the Department of Physics, National Changhua University of Education, Taiwan. This instruction was implemented in a one-semester Experimental Physics.

Experimental design

The 73 junior students were divided into two groups. One group was labeled as "OPA group" (with OPA); the other was labeled as "Traditional group" (without OPA). In addition to learning the operating principle of LEDs by SAL, the teams of OPA group were requested to review the other three teams' projects and give review comments twice at each stage. Therefore, each team received review comments from three teams to help clarify their concepts and correct the parameters of their LED design. The teams of Traditional group learned the operating principle of LEDs only by SAL and worked on the project without OPA.

Evaluation tools

As mentioned, the study measured students' knowledge, skill, and attitude in terms of three evaluation tools, a knowledge map, a photonics scoreboard, and the CPLES, respectively.

The knowledge map was adopted to evaluate the students' understanding of the principles of LED operation. In the project-based instruction procedure, students were required to present their concepts of the LED via a knowledge map both before and after the course to examine whether the OPA helped them improve their understanding of the concepts of the LED. An expert in the department of Physics, National Changhua University of Education, graded the students' knowledge maps based on the linkages between concepts. A correct proposition scored one point and an incorrect proposition scored zero points.

The study created the photonics scoreboard, built on an internet platform, for peer and expert assessments. The photonics scoreboard had five rating items: the accuracy of device structure, originality, parameter adequacy, device performance, and device applicability. Each item was scored on a scale of 1–6 points. Moreover, the scoring system provided reviewers with an open-ended column in which they could make review comments to peers' work. Students could learn from peers' work and comments, and then improve their works.

The CPLES was adopted to investigate students' perception about the effect of OPA applied in the PBL environment. Students were surveyed with the CPLES, a 5-point Likert-scale questionnaire (1 = strongly disagree, 5 = strongly agree), as shown in Table 1. The two subscales, Open-endedness and Authenticity, were used to measure the PBL environment arrangement; the other four subscales, Inquiry learning, Reflective learning, Teamwork, and Creative problem solving, were utilized to measure how the four skills were enhanced via the PBL with OPA. In analyses of the reliability and of the exploratory factor of the CPLES, the Cronbach α for the whole instrument is over 0.95, and the amount of explained variance is over 62% for each field test (Chang, 2006). Both figures were high enough to demonstrate that CPLES can be applied to assess the students' perception.

Table 1: Items for each sub-scale of the Project-Based Learning Environment Survey.

Questions for each sub-scale Upon completion of the project-based learning course, please answer the following questions.	
Inquiry learning sub-scale - I had the opportunity to: 1. Conduct research to find the answers to questions. 2. Conduct research to verify my ideas. 3. Proceed with further research to solve new problems. 4. Design/develop research methods by myself. 5. Collect data, analyze data and present the report.	Creative problem solving sub-scale - I had the opportunity to: 1. Detect errors and confirm that they were properly corrected. 2. Propose my own creative ideas. 3. Apply my creative ideas into designs or assigned tasks. 4. Evaluate all the possible solutions to problems.
Reflective learning sub-scale - I had the opportunity to: 1. Reflect on how I learn things. 2. Deliberate upon my thoughts in detail. 3. Learn how to become a better learner. 4. Present my areas of uncertainty. 5. Criticize my own research results.	Open-endedness sub-scale - The teacher let us: 1. Design methods for problem-solving by ourselves. 2. Present our own project proposals. 3. Use various types of data to solve the same problem in different ways. 4. Study the particular problems of our own that interested us. 5. Decide how to proceed with our project. 6. Solve problems from various perspectives.
Teamwork sub-scale - I had the opportunity to: 1. Use the information provided by group members to solve problems. 2. Contribute to the group goals. 3. Help other group members with their work. 4. Be a leader to teach other group members. 5. Exchange and share information or opinions with other students. 6. I loved working with my teammates.	Authenticity sub-scale 1. The problems met in this project indicate the complexity of practical problems. 2. The information presented in this project is relevant to authentic real-world problems. 3. The knowledge and experience provided by this project are relevant to authentic real-world problems. 4. The problems in this project are derived from practical problems in authentic real-world tasks. 5. Upon the completion of this project, I fully understood its objective and the subject matter.

Experimental procedure

Fig. 4 shows the procedure of the PBL with OPA. The analysis of the evaluation data were listed as follows.

RESULTS

Effect of OPA upon concept clarification

In order to determine if these two groups had the same levels of knowledge on the principles of LED operation before OPA treatment, a t-test of independent samples on the scores of knowledge map pre-test for these two groups (scores KMO-0 and KMT-0) was performed. Since the Levene test on homogeneous variance is not significant ($F = 0.014$, $p=0.908$), the t-test on the scores of pre-test could be proceeded with and the results were listed in Table 2.

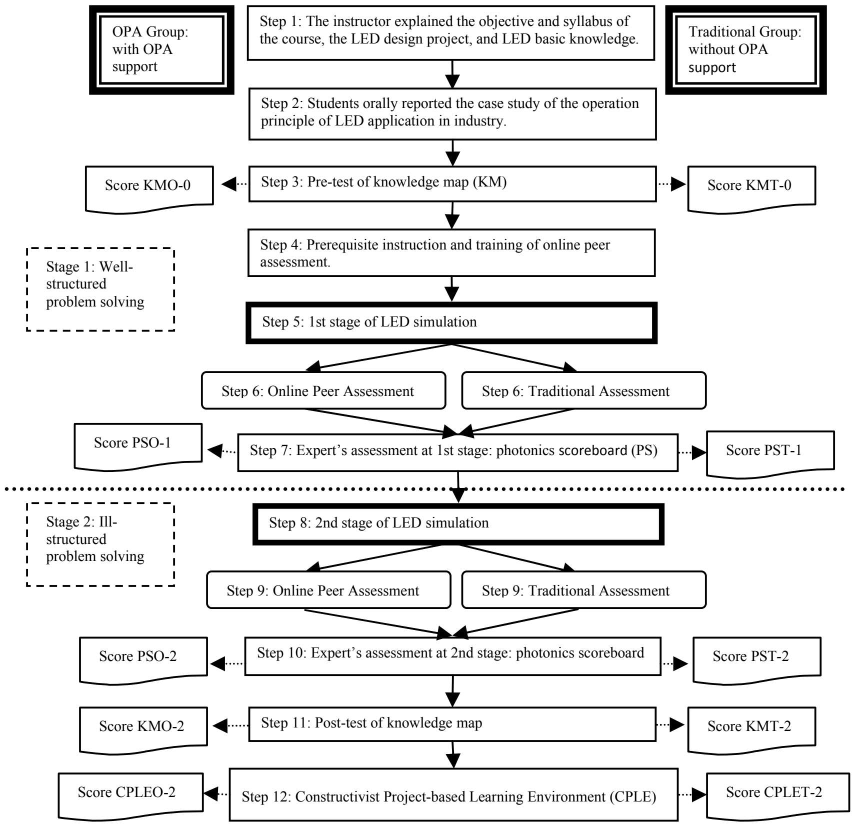

Fig. 4. Procedure of the project-based course with online peer assessment and related evaluations.

Table 2: t-test of the pre-test knowledge maps for OPA group and Traditional group.

	N	M	S.D.	t value	p value
Knowledge map pre-test of OPA group	37	2.78	1.456	1.864	0.067
Knowledge map pre-test of Traditional group	36	2.08	1.746		

* p<0.05, ** p<0.01, *** p<0.001

The pretest result revealed that these two groups had similar levels of knowledge on the principles of LED operation before proceeding with the project. To determine if the effect of OPA upon concept clarification worked significantly, the Levene test on homogeneous variance was adopted firstly ($F = 3.965$, $p=0.050$), and the t-test on the scores of knowledge map post-test for these two groups (scores KMO-2 and KMT-2) were listed in Table 3.

Table 3: t-test of the post-test knowledge maps for OPA group and Traditional group.

	N	M	S.D.	t value	p value
Knowledge map post-test of OPA group	37	5.16	1.21	3.767*	0.000*
Knowledge map post-test of Traditional group	36	3.69	2.03		

* p<0.05, ** p<0.01, *** p<0.001

The t-test result revealed that the scores of OPA group on knowledge map post-test is significantly higher than those of Traditional group, which means the effect of OPA upon concept clarification worked significantly.

Effect of OPA upon enhancing LED design skills in well-structured problem solving

To determine if the effect of OPA upon enhancing LED design skills in well-structured problem solving worked significantly, the Levene test on homogeneous variance was adopted firstly ($F = 1.132$, $p=.291$), and a t-test on the expert's assessment scores of photonics scoreboard on well-structured problem solving for these two groups (score PSO-1 and PST-1) were listed in Table 4.

Table 4: t-test of the expert's assessment scores on well-structured problem solving for OPA group and Traditional group.

Well-structured problem solving	N	M	S.D.	t value	p value
Expert's assessment scores of photonics scoreboard for OPA group	37	21.73	1.503	5.136^{***}	0.000
Expert's assessment scores of photonics scoreboard for Traditional group	36	20.03	1.320		

* p<0.05, ** p<0.01, *** p<0.001

The t-test result revealed that the scores of OPA group on photonics scoreboard is significantly higher than those of Traditional group, which means the effect of OPA upon enhancing LED design skills in well-structured problem solving worked significantly.

Effect of OPA upon enhancing LED design skills in ill-structured problem solving

To determine if the effect of OPA upon enhancing LED design skills in ill-structured problem solving worked significantly, the Levene test on homogeneous variance was performed (F = 2.037, p=.158), and a t-test on the expert's assessment scores of photonics scoreboard on ill-structured problem solving for these two groups (score PSO-2 and PST-2) were listed in Table 5.

Table 5: t-test of the expert's assessment scores on ill-structured problem solving for OPA group and Traditional group.

Ill-structured problem solving	N	M	S.D.	t value	p value
Expert's assessment scores of photonics scoreboard for OPA group	37	21.86	.585	-1.029	0.307
Expert's assessment scores of photonics scoreboard for Traditional group	36	22.00	.535		

* p<0.05, ** p<0.01, *** p<0.001

The t-test result revealed that there is no significant difference between the scores of these two groups, which means the effect of OPA upon enhancing LED design skills in ill-structured problem solving did not work significantly, though it did in well-structured problem solving.

Students' perception about the effect of OPA applied in PBL

To determine if students agree that OPA applied in PBL worked significantly, a t-test on CPLES for these two groups (scores CPLEO-2 and CPLET-2) were listed in Table 6.

Table 6: t-test of the scores in Constructivist Project-based Learning Environment Survey for OPA group and Traditional group

Sub-scales	A		B		t-test	
	N=35		N=30		t value	p value
	M	S.D.	M	S.D.		
Inquiry learning	3.70	0.41	3.42	0.53	2.435	0.018^{*}
Reflective learning	3.81	0.41	3.60	0.38	2.142	0.036^{*}
Teamwork	3.93	0.40	3.77	0.46	1.461	0.149
Creative problem solving	3.71	0.57	3.64	0.49	0.494	0.623
Open-endedness	3.62	0.69	3.62	0.56	0.015	0.988
Authenticity	3.54	0.54	3.51	0.60	0.257	0.798

* p<0.05, ** p<0.01, *** p<0.001

The t-test result revealed that the scores of OPA group on the subscales of CPLES, inquiry learning and reflective learning, were significantly higher than those of Traditional group, which means OPA group outperformed Traditional group on enhancing students' inquiry learning and reflective learning. However, for the other two subscales, Creative problem solving and Teamwork, there is no significant difference between these two groups.

Interview results- qualitative feedback

In order to gather an in-depth understanding of students' behavior and the reasons that govern such behavior, we collected the feedback from the final project presentations of each group and then conducted in-depth interviews with them several times after the presentation. The interviews were recorded and encoded. S1 represents the interview results with OPA group; S1-1 represents the interview with the number one team of OPA group. S2 represents the interview with Traditional group, and so on.

Students' opinions on online peer assessment

S1-1: Comments and advice from others is helpful to refine our work, but assessing other's work is even more important and we learn more.

S1-3: We could learn useful knowledge and practical skills from this interesting course. At the beginning, we do not know how to review other's work…we were not sure if our suggestions is correct or not, but after two or three OPA experience, we had more confident when rating our peer.

S1-4: Although the figure did not match the requirement at the first try, we adjusted the parameters according to comments from classmates, and the results were better.

S1-6: According to the simulation results and online PA, we could summarize the regulation of parameter adjustment, and generalize the operating principle of LEDs.

Students in OPA group considered that OPA helped them improve their works effectively. Students of the first, third, fourth, and sixth teams agreed that OPA could help them to modify their works by taking others' comments. However, some complains which could be a valuable reference to improve the implementation of OPA in PBL were listed as follows.

S1-2: Because we had too much subjects to learn in this (junior) year, we could not do our best in this course especially in OPA. Besides, we needed to start preparing for the entrance examination of graduate schools at this year.

S1-3 & S1-5: Most of the review comments worked well at the beginning, but sometimes they failed later and misled our focus in the wrong direction on problem solving. We doubted that some reviewers tried to give wrong comment purposely for the sake of getting competitive advantages.

S1-4: We always waste much time in adjusting parameters by guessing. When you adjust a new parameter, you have to rerun this program and it took a long time.

Students in OPA group showed an over-reliance on the review comments. Moreover, the second/one more in-dept interview with OPA group members were conducted and it revealed that the prior success experiences which were referred from the review comments as well as their own thinking might also misled or limit their thinking. Furthermore, the first priority of these students was passing the entrance examination of graduate schools to fulfill with the expectation from their parents or society. Therefore, they push themselves very hard to learn effectively and prevent from making any "try and error" which could be harmful to enhance their meta-cognitive skills and self regulation learning.

Students' opinions on two-stage LED simulation of PBL course

Some comments were made by Traditional groups.

S2-1: The two-stage LED simulation of PBL was interesting yet challenging. We learned useful things from the course.

S2-2 & S2-6: At the very beginning, we felt excited while we knew this PBL course would be provided for us at this semester, but we are frustrated to design LED by guessing the parameters. We are not used to this course; we have no idea how to adjust the parameters from the huge scope of numbers.

S2-3, S2-4 & S2-6: We suggest that the teacher give us more references so that we could use them to optimize our parameters.

According to the interview results, we discovered that students of both Traditional and OPA groups were not used to such instruction and some of them could not learn independently and actively, which could be the problem for most of students in Taiwan. Some of them also demonstrated a lack of self-confidence when rating their peer, which is similar to the previous studies (Orsmond & Merry, 1996; Sullivan, Hitchcock, & Dunnington, 1999). Students thought that failure caused frustrations and cost too much time. The second and sixth teams of Tradition group indicated that this course differed from those they had taken previously, so they feel excluded and frustrated. Furthermore, students hoped that the teacher could provide more knowledge and hints about the parameters of LED; the students showed an over-reliance on books as well as teacher's assistance, and were not able to search for information actively.

CONCLUSIONS

The study addressed and explored how to apply OPA according to the structured level of a problem in a PBL course to enhance students' professional skills in LED design as well as meta-cognitive thinking. The evaluation results elicit the following relevant facts:

(1) OPA group performed better than Traditional group in concept clarification.

(2) For the enhancement of LED design skills in well-structured problem solving, OPA group performed better than Traditional group.
(3) For the enhancement of LED design skills in ill-structured problem solving, there was no significant difference between the performances of these two groups.
(4) For students' perception about the effect of OPA applied in PBL, OPA could enhance students' inquiry learning and reflective thinking skills but creative problem solving and teamwork skills. Most students agreed that the two-stage LED simulation of PBL course was challenging and interesting and they learned useful things from the course. However, the students showed an over-reliance on the review comments or prior success experiences and lost their independent and critical thinking abilities.

Most students of OPA considered the PBL course with OPA to be an effective tool in understanding operating principle of LEDs and clarifying concepts which were similar to the studies of Topping (1998), Wen & Tsai (2006), and Liu & Lin (2007). However, the OPA did not work significantly to enhance the students' professional skills in LED design as well as meta-cognitive thinking in ill-structured problem solving.

DISCUSSION AND SUGGESTIONS

This study has provided useful evidence on OPA that is applied in PBL, which can help university students clarify concept as well as enhance their inquiry learning, reflective thinking abilities and LED design skills in well-structured problem solving. However, there are some limitations for OPA in ill-structured problem solving as described below.

First, the students of OPA declined their learning passions when they failed to solve the ill-structured problems according to the peers' review comments after several tries. The students showed an over-reliance on the review comments or prior success experiences and lost their independent and critical thinking abilities. The Einstellung effect (set effect) occurs when the first idea that comes to mind, triggered by familiar features of a problem, prevents a better solution being found. It has been shown to affect both people facing novel problems and experts within their field of expertise (Bilalic, McLeod, & Gobet, 2008). It makes learner become inflexible to deal with novel/ill-structured problems, which is harmful to skill learning and skill transfer (Luchins, 1942; Gagne, Yekovich, & Yekovich, 1993). Moreover, the quality of problem definition determined the quality of solution (Getzels, 1975). In the study, some teams of OPA group were misled to the wrong direction in problem definition or solving which were suggested by peer reviewers. Teacher-facilitators could provide a scaffold example to show students how to generate "smart tries" systematically as well as monitor the learners to function systematically (planning, implementing, asking questions/reflective thinking and seeking input adjustment) and reflect on their learning at the end of each try.

Secondly, insufficient time and lack of motivation declined students' participation in OPA. A very unusual phenomenon in Taiwan is that university students started to focus on the preparation for the entrance examination of graduate schools since their sophomore year or junior year. Thus, they do not have enough time to do their best in this course because passing the entrance examination of graduate schools to fulfill with the expectation from their parents or society is the first priority. Besides, some students commented that they learned slowly and they needed more time to get the project done. Wallas (1926) pointed out that a creative problem solving process involved four stages, i.e., preparation, incubation, illumination, and verification, which all took time to implement. Therefore, stimulating students' motivation required more precaution when the course was developed and implemented.

LIMITATIONS

Even though a rigorous research procedure was used, this work has some imitations that could be addressed in future studies. First, a quasi-experiment design was adopted without detailing the individual difference of learners. Individual difference variable, such as learning style, could be a direction for future study. Second, the findings and implications are obtained from just one study that examined a particular computer simulation software (i.e., APSYS) and targeted a specific group in Taiwan. Moreover, the OPA group might have more out-of-class time to work on their project than the traditional group, even though both OPA group and Traditional group students were required to finish their projects of each stage during the scheduled time. Hence, the positive effect could be partly attributed on more learning time than the intervention (i.e., OPA) alone. Thus, caution must be taken when generalizing our findings and discussion to other educational technologies or groups. Third, the students in Taiwan have unique value and behavior patterns, such as they had different definition on learning achievement and their first priority was to pass the entrance examination. Therefore, a cross-cultural validation using another large sample gathered elsewhere is required for further generalization of our findings.

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