In: E-Learning: 21st Century Issues and Challenges ISBN : 978-1-60456-156-2
Editor: A.R. Lipshitz and S. P. Parsons

Chapter 8

WHEN COLLABORATIVE PBL MEETS E-LEARNING: HOW DOES IT IMPROVE THE PROFESSIONAL DEVELOPMENT OF CRITICAL-THINKING INSTRUCTION?

Yu-chu Yeh
Institute of Teacher Education and Research Center for Mind, Brain & Learning
National Chengchu University, Taiwan

ABSTRACT

This study investigated whether collaborative PBL in conjunction with blended learning would improve preservice teachers' critical-thinking skills. Employing the before-and-after design, the researcher conducted an 18-week experimental instruction program with 34 preservice teachers enrolled in an undergraduate class of "Critical-thinking Instruction." The program incorporated collaborative PBL with blended learning, where face-to-face instruction was combined with e-learning. It was found that: (a) all participants held positive views about the instructional design of this study, claiming that it provided them with opportunities to put theory into practice, increased their motivation to participate, encouraged authentic thinking, and provoked multiple-perspective thinking; (b) the experimental instruction considerably improved the preservice teachers' critical-thinking skills; and (c) the precise mechanisms that facilitated such positive effects were evidently the problem-based learning, guided practice, discussions and sharing, observational learning, and the self-reflection activity.

Key words: blended learning, collaborative PBL, critical-thinking skills, E-Learning.

Critical thinking is a thought mode for generating knowledge (Schroyens, 2005), an effective learning strategy (Browne & Meuti, 1999; Gadzella & Masten, 1998; Halpern, 1998; McCarthy-Tucker, 2000), and a prerequisite for success in business (Harris & Eleser, 1997). A particularly recent surge of interest in teaching critical thinking and advances in online

education have been driving forces behind the development of methods for professional development in critical-thinking instruction via e-learning.

To be an effective instructor of critical thinking, solid critical-thinking skills are required. To date, many researchers (e.g., Carmen & Kurubacak, 2002; Ellis, 2001; Mackinnon, 2006; Nelson & Oliver, 2004) have conducted research focusing on the use of e-learning to develop learners' critical-thinking skills and have found positive effects. In related research, two important teaching approaches have aroused a great deal of interest. First, problem-based learning (PBL) is a constructivist educational approach that organizes curricula and instruction around a carefully-crafted "ill-structured" problem. This is expected to help students develop their critical-thinking skills, problem-solving abilities, and collaborative skills as they identify problems, formulate hypotheses, conduct data searches, formulate solutions, and determine the best "fit" solution to a given problem (Ram, Ram, & Sprague, 2004). Some research (e.g., Albion & Gibson, 2000; Ochoa et al., 2001) have reported that PBL is an effective teaching approach used in professional executive training. Recently, the concept 'collaborative PBL' has sparked considerable interest and gained increasing popularity. Collaborative PBL stands apart from traditional PBL since learners experience personal and social cognitive conflicts within the context of a discussion and their goal is to collectively disentangle these conflicts by explaining the reasoning behind their thinking with one another in the group (Lee & Kim, 2005). The second important teaching approach involves blended learning which combines face-to-face instruction and e-learning. It has in fact been found to be a more effective approach than a pure e-learning approach (Osguthorpe & Graham, 2003). With these two promising approaches in mind, this study integrated collaborative PBL with blended learning in order to investigate whether it could improve preservice teachers' critical-thinking skills. This study also explored the mechanisms that could contribute to such an improvement.

CRITICAL-THINKING SKILLS

Critical-thinking skills are often referred to as higher-order thinking. Higher-order thinking, which is reflective, sensitive to the context, and self-monitored, requires synthesis, analysis, and judgment (Halpern, 1998). Numerous definitions of critical thinking have been proposed (e.g., Bailin, Coombs, Browne & Meuti, 1999; Giancarlo & Facione, 2001; Halpern, 1998, 2003; McCarthy-Tucker, 2000; Paul & Elder, 2001). Halpern (1998), for example, defined it as purposeful, reasoned, and goal-directed, further arguing that it is the kind of thinking that involves solving problems, making inferences, calculating likelihoods, and making decisions. Paul and Elder (2001) state that critical thinking is a mode of thinking in which the thinker improves the quality of his or her thinking by skillfully taking charge of the structures inherent in thinking and imposing intellectual standards upon them. To sum up, critical thinking is self-disciplined, self-monitored, self-directed, and self-corrective thinking, and it typically involves effective communication and problem-solving skills. Paul and Elder characterize a well-cultivated thinker as someone who:

- Raises vital questions, identifies problems, and formulates these clearly and precisely;
- Gathers and assesses relevant information, and can effectively interpret it;
- Comes to well-reasoned conclusions and solutions, and can test them against relevant criteria and standards;
- Thinks openmindedly within alternative systems of thought, and can recognize and assess assumptions, implications, and practical consequences in those alternative systems; and
- Communicates effectively with others in devising solutions to complex problems.

In terms of the cognitive processes involved in critical thinking, Marzano claimed that it comprises 8 stages: concept formation, principle formation, comprehension, problem-solving, decision-making, research, composition, and oral discourse (as cited in Bailin et al., 1999). But, Daniel Eckber contended, stating that critical thinking involves 6 steps: defining dilemma, evaluating electives, considering consequences, determining importance, deciding on direction, and assessing ends (as cited in Bailin et al., 1999). In light of the above, there can be little doubt that critical thinking is closely related to problem-solving.

PBL AND COLLABORATIVE PBL

PBL provides great possibilities for improving learning (Mayo, Donnelly, Nash, & Schwartz, 1993). Since first developed in medical schools as a means to prepare interns students for their future profession (Savery & Duffy, 1995), PBL has been employed in various domains to improve learning.

Delisle (1997) defined PBL as a teaching technique that requires students to solve problems in a certain situation. Students are assigned to teams that are responsible for framing a problem and deciding how best to use their knowledge to solve it (Engel, 1997). Moreover, the goals of PBL are to familiarize students with the types of problems that they may face in the future, equip them with relevant knowledge, facilitate their application of problem-solving skills, and finally help them refine their problem-solving skills (Gerber, English, & Singer, 1999; Savery & Duffy, 1995).

According to Savery and Duffy (1995), there are four major features in PBL:

- Students develop a new cognition with each goal;
- All problems proposed by the teacher are related to students' real-life;
- Both the problem and the teacher play a part in increasing learners' learning motivation; and
- The teacher is a facilitator during the learning process.

Egg and Kauchak (2001) claim that PBL strategies typically have the following characteristics:

- Lessons begin with a problem or question, and solving the problem is the focus of the lesson;
- Students are responsible for investigating the problem, designing strategies, and finding solutions; and
- The teacher guides students' efforts through questioning and other forms of instructional scaffolding.

As for the learning process, Boud (1985) reported that PBL begins with the presentation of a problem. Students then work in small groups to analyze the problem and decide what information is required for a solution. Once they identify the required learning, students begin individual work and conduct research before returning to the group to share their thoughts and findings concerning the problem. In the final phase, in groups, students are asked to summarize and integrate what they have learned. In the same vein, Jordan and Porath (2006) claim that PBL involves working in cooperative groups and thinking about real-world problems. These descriptions of PBL indicate that, in essence, it must be conducted in a collaborative way. As a result, collaborative PBL has now become a more widely-used term.

According to Lee and Kim (2005), collaborative PBL is a learning method in which learners have a common goal, in which they perform given tasks at the same level, and in which they interact with one another while problem-solving. Accordingly, collaborative PBL emphasizes the importance of interactive discussions; this is based on the principals of social constructivism which emphasizes that learning is achieved via negotiating thoughts and building mutual understanding with others. In other words, collaborative PBL is the product of social interactions through negotiations and mutual understanding (Littleton & Hakkinen, 1999).

Apart from this, in collaborative PBL, learners are expected to construct a problem representation and to manipulate the problem space, transferring their internal representations into external ones (Lee & Kim, 2005). Representation tools mediate collaborative learning interactions by providing learners with the means to express their newly-created knowledge in a stable medium, where the new knowledge then becomes part of the shared context. In this sense, concept maps provide an effective presentation tool (Lee & Kim, 2005). A concept map is a drawn picture that reflects a learner's understanding and interpretation of various aspects of a given topic (Raymond, 1997). In that PBL requires learners to summarize and systemize relevant information when searching for a solution to a problem, concept maps not only provide learners with summarized information that contributes to learning, but also provide learners with a framework that helps them when they systematize materials in a particular knowledge domain (Alvermann, 1986; Moore & Readence, 1984; Novak, 1984; Novak & Gowin, 1984; Stewart, 1984). Concept mapping, therefore, can be an ideal vehicle for visualizing relevant arguments for use in problem-solving.

In addition to this, PBL generally includes case studies which have been recognized as valuable instructional tools (Carter & Unklesbay, 1989; Merseth & Lacey, 1993). When PBL includes this approach, students are presented with a problem embedded within the resource-rich context of a case study, and assuming the role of primary researchers, they proceed to analyze the problems, come up with and weigh all possible solutions, develop a plan and evaluate all possible outcomes (Simons, Klein, and Brush, 2004). Such a rich context as a case study, therefore, encourages, if not necessitates, the employment of critical-thinking skills.

COLLABORATIVE PBL AND BLENDED LEARNING

E-learning has five particularly salient features (Rich, 2001). First, it is available via the Internet at any time and place. Second, its multi-faceted format allows for relatively high levels of interactivity. Third, the contents can be adapted on the basis of individual needs and advancement opportunities. Fourth, learning experiences range from very basic exercises to highly interactive forms of communication, and from textbook learning to performance simulation. Finally, a web-based learning management system has the capacity to track attendance, record test scores, and even correlate training effectiveness with business results.

In addition, e-learning encompasses various communication modes in both synchronous and asynchronous modes. Synchronous discussions take place in real time, which means participants communicate with each other at the same time. Asynchronous discussions, on the other hand, do not take place in real time and allow for delays in receiving and responding to communications; these are often referred to as threaded discussions, asynchronous conferencing, electronic discussion boards, or text-based computer conferencing (Beaudin, 1999). Among these media, the asynchronous discussion board is by and large the most frequently used; it not only encourages thoughtful reflection and more complex responses, but also enhances collaboration and provides greater flexibility and convenience for group discussions (Rossman, 1999).

Given the advantages of PBL and e-learning, integrating them should make it possible to maximize the acquisition of critical-thinking skills. One example of the successful integration of PBL and e-learning is cited in the study of Garrison, Anderson, and Archer (2001) who employed computer-mediated communication in PBL to improve students' critical-thinking skills; more specifically, based on the concepts of problem-solving, they employed a four-stage process: (1) triggering: posing the problem; (2) exploration: searching for information; (3) integration: constructing possible solutions; and (4) resolution: critically assessing different solutions. Lee and Kim (2005), however, suggest that although a web-based collaborative PBL environment has great potential for cultivating the ability to solve problems in practical situations, compared to traditional classrooms, it offers learners relatively few opportunities to solve problems through face-to face interactions. In a case study involving of the ITESM-CCM, the most competitive private higher education institution in Mexico, Mortera-Gutiérrez (2006) finds that the worst teaching approach takes place when instructors make their e-learning platform the main engine of their courses and totally overlook face-to-face instruction. Blended learning, which combines face-to-face instruction with e-learning, can maximize the benefits of both face-to-face and online methods (Osguthorpe & Graham, 2003). Therefore, with the complementary use of e-learning, especially that with asynchronous discussion boards, it is expected that collaborative PBL is considerably more effective in the classroom than a pure approach which only employs either face-to-face instruction or e-learning, not both.

COLLABORATIVE PBL, E-LEARNING, AND CRITICAL THINKING

Very little research has investigated the relationship between collaborative PBL in a blended learning context and teachers' professional development in teaching critical thinking Owing to the paucity of research in this line of study, the following literature review mainly centers on the relationships between PBL or collaborative PBL and critical thinking as well as the relationship between e-learning and critical thinking.

There is no question that many researchers (e.g. DaRosa, D. A., ÓSullivan, P. S., Younger, M., & Deterding, R., 2001; Kamin, C., ÓSullivan, P., Deterding, R., & Younger, M., 2003; Semerci, N., 2006; Tiwari, A., Lai, P., So, M., & Yuen, K., 2006) take the position that PBL can significantly improve critical-thinking skills. Tiwari, Lai, So, and Yuen (2006), for example, compared the effect of PBL with that of lecturing approaches on the development of students' critical thinking and found that those who took PBL courses made considerably greater improvements in their critical-thinking dispositions than their counterparts who merely took lecture courses. In the same vein, in his study comparing the beneficial effects of PBL with those of traditional teaching methods on students' critical thinking, Semerci (2006) finds that the former far surpassed those of the latter,.

As for the relationship between e-learning and critical thinking, previous findings (e.g., Carmen & Kurubacak, 2002; Ellis, 2001; Kumta, Tasng, Hung, & Cheng, 2003; Mackinnon, 2006; Nelson & Oliver, 2004) suggest that e-learning provides a natural framework for the strengthening of critical-thinking skills. For example, based on their study designed to stimulate the abilities of analysis, application, and evaluation, Kumta et al. (2003) find that a web-based tutorial program can foster medical students' critical-thinking skills. Along similar lines, Ellis (2001) finds that computer-based multimedia tutorials do help students develop their critical-thinking skills. And, integrating electronic discussions with electronic concept mapping, Mackinnon (2006) concludes that preservice teachers were able to significantly improve their ability to both formulate arguments and lead effective discussions. These findings suggest that the e-learning interface enables participants to express their opinions using sound reasoning, to develop arguments supported by logic and solid evidence, and to reflect on and share ideas with others by making thinking transparent.

Hughes and Daykin (2002) suggest that with the move to online delivery, greater attention must be paid to the design and development of facilitator skills than previously thought. From a constructivist viewpoint, a critical component of online interaction is the interpersonal/social component. Social interaction can contribute to learner satisfaction and increase frequency of interaction in an online learning environment. Blended learning emphasizes social interaction and it places a high priority on the objective of using technological resources in critical and reflective ways in the classroom; moreover, blended learning provides opportunities for sharing information in a faster way, while creating a positive educational environment for feedback (Mortera-Gutiérrez, 2006). Therefore, as long as a teaching program is well designed, the integration of PBL and blended learning should benefit preservice teachers by helping them to improve their critical-thinking skills. This study therefore hypothesized that integrating collaborative PBL and blended learning should effectively improve preservice teachers' critical-thinking skills.

METHOD

Participants

The participants were 34 preservice teachers (6 males and 28 females) enrolled in the Critical-thinking Instruction class in a teachers' training program for secondary school teachers. Among them, 16 (47.1%) were undergraduates and 18 were graduates (92.9%). Their mean age was 23.00 (*SD* = 2.54).

Instruments

The instruments employed in this study were the e-learning website developed by National Chengchi University, the *Critical Thinking Test, Level II* (CTT-II), the *Situation-based Critical Thinking Test* (SB-CTT), and a reflection questionnaire.

The structure of the e-learning interface consists of curricular content, curricular information, curricular interaction, an individual area, and a system area (see Figure 1). The instructional design in this study required participants to complete a project based on PBL which required a great deal of online discussions; as a result, the "discussion board" under "curricular interaction" was the most commonly used interface.

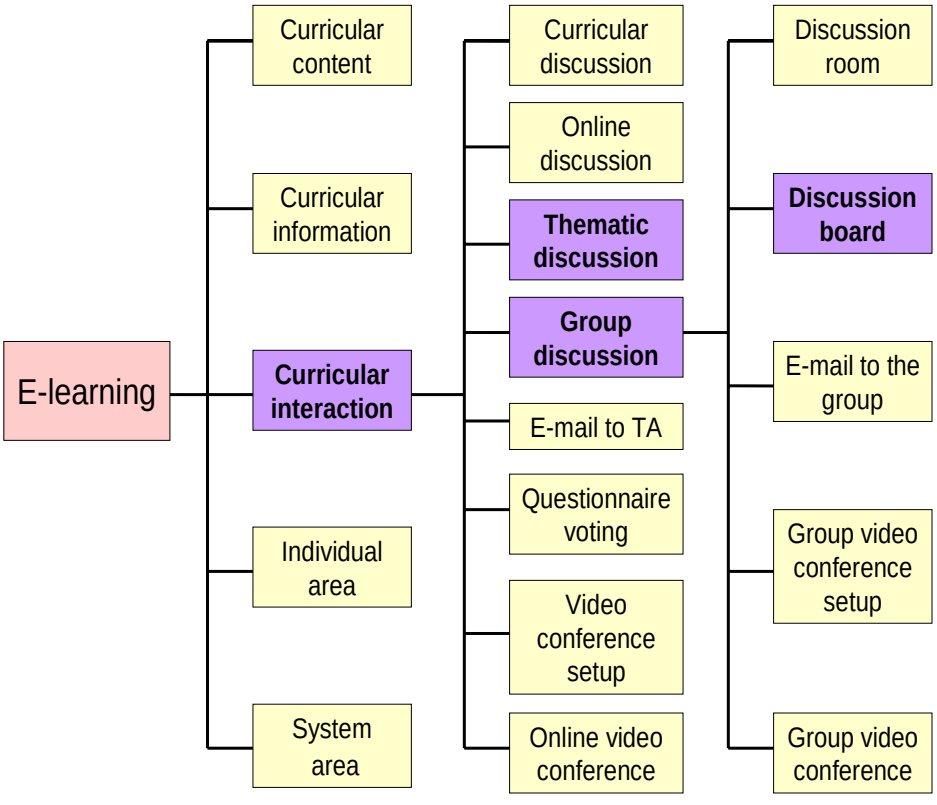

Figure 1. Structure of the e-learning interface.

The CTT-II, based on the *Cornell Critical Thinking Test* (Ennis, Millman, Tomko, 1985) and the *Watson-Glasser Critical Thinking Test* (Watson & Glasser, 1980), was developed by Yu-Chu Yeh (2005). It consists of 30 multiple-choice items evenly divided into five subtests: assumption identification, induction, deduction, interpretation, and argument evaluation. Each item consists of one statement and four multiple-choice answers. With a 25-minute time limit, the CTT-II has a total possible score of 30 points. In this study, a correct answer was given a score of 1 point and a wrong answer 0. The average discrimination index of the CTT-II is .35 (with a range of .21 - .53) and the average difficulty index is .58 (with a range of .24-.84). The test can effectively discriminate between the high-ability group (upper 27%) and the low-ability group (lower 27%) on the ability to think critically. Moreover, the subtest scores and total score are significantly correlated, rs (492) = .352 - .665, ps < .001 (Yeh, 2005).

The SB-CTT, developed by Yu-Chu Yeh (2005), is based on Paul and Elder's (2001) concepts of 10 intellectual standards and 8 reasoning elements. This test consists of a paragraph entitled *The Life of Albert* and 7 open-ended questions. With the theme "being happy", the paragraph describes Albert's beliefs and thoughts about life. It also consists of several assumptions and a few personal feelings or characteristics, such as being happy, selfish, pessimistic, and being irresponsible, as well as believing in fate. After reading the paragraph, the participants were required to analyze the paragraph from seven perspectives: (1) purpose and information; (2) issues; (3) assumptions; (4) points of view; (5) inferences; (6) implications; and (7) evaluation (Yeh, 2005). In this study, a consensual assessment by two trained graduate students was employed to score the responses in this test.

Finally, a reflection questionnaire, consisting of 9 open-ended questions, was developed by the researcher based on the research needs and contents of the experimental instruction. Each of the 10 questions and a summary of the responses are given in the Results section.

Procedures

This study employed the before-and-after design. An 18-week experimental instruction program integrating collaborative PBL and blended learning was implemented. The pretests were administered in the first week, and the posttests in the 18th week. The pretests comprised the CTT-II and the SB-CTT, while the posttests comprised all of the pretests as well as the reflection questionnaire. In the second week, the participants were put into their self-assigned groups of 5-6 for a total of 6 groups and started to prepare for their project in which PBL was implemented

During the instruction period, throughout the first seven weeks, the researcher introduced the concepts of critical thinking and related strategies. Meanwhile, the participants were asked to find a suitable case on which to develop arguments based on PBL. From the 8th week on, the participants were provided scaffolding to complete the PBL assignment. During this period of learning, the researcher also asked that the participants construct a group contract consisting of learning goals and conflict resolutions, a concept map depicting the arguments they prepared for problem-solving, and a role play to act out the process of solving the authentic problem they had chosen. At the end of the 18-week course, the participants were asked to reflect on their PBL experiences by compiling a learning portfolio in which they described the developmental steps in their learning under PBL. Added to this, the participants were encouraged to read other groups' homework online and to use the e-learning interface,

especially the discussion board, to complete their project. More specifically, the case study approach along with the strategies of concept mapping, role play, observational learning, guided practice, cooperative learning, and self-reflection were adopted to scaffold the participants to complete their PBL assignments in this study.

Data analysis

To evaluate the participants' performance on the CTT-II and the SB-CTT, several one-way (within group: pretest vs. posttest) Repeated Measure Analyses of Variance were performed.

RESULTS

Improvements in critical-thinking skills

This study employed the CTT-II and the SB-CTT to determine whether the participants' critical-thinking skills had improved since the onset of the experimental instruction. Table 1 and Figure 2 depict the means and standard deviations as well as the patterns of change in the participants' performance on the subtests of the CTT-II. The Repeated Measure Analysis of Variance indicates that Test (pretest vs. posttest) had a significant effect on the CTT-II scores, F (1, 26) = 9.194, p = .005, η^2 = .261(See Table 2). A comparison of the means makes it clear that the participants performed better on the posttest than on the pretest.

Table 1. Participants' Mean Scores and Standard Deviations on the Subtests of the CTT-II

	Pretest			Posttest		
Test	*N*	*M*	*SD*	*N*	*M*	*SD*
Assumption	27	3.11	1.40	27	2.70	.95
Induction	27	4.41	.89	27	4.78	.80
Deduction	27	3.44	1.31	27	4.07	1.44
Explanation	27	2.93	1.38	27	3.26	1.29
Evaluation	27	2.30	1.10	27	3.07	1.00

Table 2. Test Results of Within-Subjects Contrasts on the Total Score of the CTT-II

Source	*M*	*SD*	Type III SS	*df*	*MS*	*F*	Sig.	η^2
Pretest	16.19	2.54	39.185	1	39.185	9.194	.005	.261
Posttest	17.89	2.82						

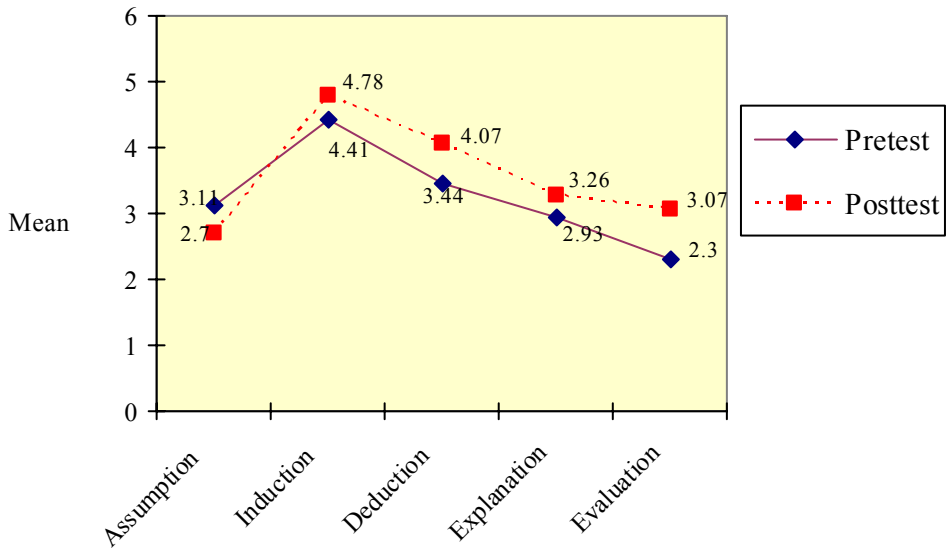

Figure 2. Changes in the patterns of participants' performance on the subtests of the CTT-II.

Table 3 and Figure 3 depict the means and standard deviations as well as the changes in the patterns of the participant' performance on the subtests of the SB-CTT. The Repeated Measure Analysis of Variance indicates that Test (pretest vs. posttest) had a significant effect on the CTT-II, F (1, 31) = 42.136, p = .000, η^2 = .584 (See Table 4).. A comparison of the means again confirms that the participants performed better on the posttest than on the pretest

Table 3. Participants' Mean Scores and Standard Deviations on the Subtests of the SB-CTT

	Pretest			Posttest		
Test	*N*	*M*	*SD*	*N*	*M*	*SD*
Q1	32	3.75	.508	32	3.97	.315
Q2	32	3.25	.672	32	3.55	.810
Q3	32	3.31	.535	32	3.39	.667
Q4	32	3.88	.871	32	3.87	.670
Q5	32	3.53	.671	32	4.23	.425
Q6	32	3.16	.448	32	3.29	.461
Q7	32	2.81	.471	32	4.06	.250

Table 4. Test Results of Within-Subjects Contrasts on the Total Score of the SB-CTT

Source	*M*	*SD*	Type III SS	*df*	*MS*	*F*	Sig.	η^2
Pretest	23.61	2.14	116.532	1	116.532	42.136	.000	.584
Posttest	26.35	2.17						

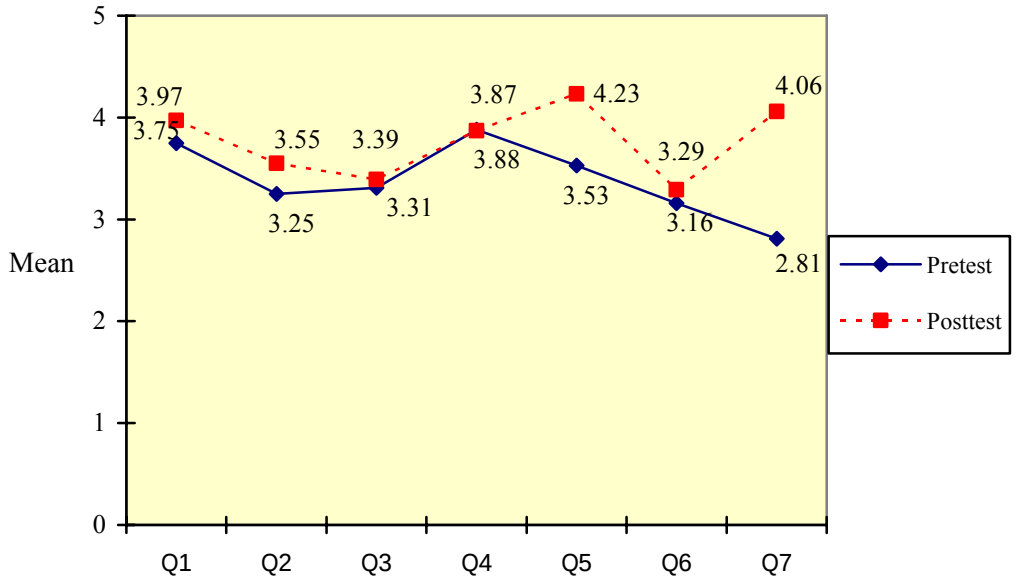

Figure 3. Changes in the patterns of participants' performance on the subtests of the SB-CTT.

Mechanisms for improving critical-thinking skills

This study analyzed the different mechanisms intended to improve critical-thinking skills. A summary of the results based on the participants' answers on the reflection questionnaires is presented in the following.

- Have you read the other groups' work online and how do you feel about having the opportunity to read their work? Why?

All the participants claimed to have read the other groups' work online and to have benefited from it. The primary benefits were that it helped them to better self-reflect by observing the work of others (26%); it gave them a chance to practice their own critical-thinking skills (23%); the other groups' work served as examples (19%); the other groups' work gave them inspiration and stimulated new ideas (16%); and it helped them to understand the contents of the curriculum (10%).

- This class integrated PBL and blended learning. Did such an instructional design contribute to the improvement in your critical-thinking skills? How?

Ninety-seven percent of the participants reported that this instructional design contributed to the improvement in their own critical-thinking skills. The principal ways in which it helped them were that it increased their opportunities for online discussions (19%); online discussions increased their opportunities to practice critical-thinking skills (19%); observing

the performance of others helped them solve problems on their own (11%); the integration of PBL and blended learning improved their thinking skills and knowledge (10%); it helped them better retain class learning and gave them motivation to participate more actively (10%); and it provided them with opportunities to exchange information and clarify relevant concepts (10%).

- Did the instructional design encourage you to reflect on your critical-thinking skills, attitude, and teaching? Why?

All the participants responded to this question in the affirmative. The main reasons were that the discussion and interaction encouraged self-reflection (55%); the online learning was convenient for extensive learning and discussions (35%); and it helped them with their teaching (10%).

- What were the benefits of the blended learning—that is, e-learning integrated with classroom learning? Why?

All the participants had a positive attitude about the blended learning and were very willing to share their ideas. The main benefits they cited were that it was very convenient for group discussions and for completing assignments (48%); it increased their opportunities to review and practice critical-thinking skills outside the classroom (23%); it increased their opportunities to share reports (13%); and it saved time and resources (10%).

- Did the learning contract enhance the spirit of cooperation among you and your group members and help you with the completion of group tasks? Why?

Sixty-eight percent of the participants agreed with this statement and the main reasons included the fact that it kept everyone on track and helped them resolve conflicts among group members (52%); it helped them establish rules and therefore improved their sense of belonging to the group (13%). On the other hand, some participants challenged the notion, contending that the contract did not have much influence as all group members had already been working hard from the start (20%).

- Did the use of the real-world cases in PBL contribute to your learning of critical thinking? Why?

All the participants held positive attitudes toward this question. The main reasons were that the case studies helped them integrate theory into practice (25%); the case studies were authentic and therefore made sense to them (23%); and they provoked multi-perspective thinking and critical thinking (10%).

- Did the use of role plays to act out your arguments contribute to your learning of critical thinking? Why?

Most participants (94%) had positive feelings about the role plays. This seemingly stemmed from their highly interactive and interesting nature. They responded that the role plays provoked empathy and multiple-perspective thinking (48%), helped audiences to understand their arguments (30%), and increased their friendships with other group members (10%). A few participants, however, claimed that the role plays did not contribute to their learning of critical thinking (3%) and that the role plays gave group members unnecessary stress (3%).

- Did the representation of arguments via concept mapping contribute to your improvement in critical thinking? Why?

All the participants agreed that concept mapping was valuable and the reasons cited were that it helped them with the presentation and systemization of complex thinking (29%); it helped them with the drawing of conclusions from complex data, which further became good arguments (26%); it helped them understand the relationships among concepts since it visually compared and contrasted them (23%); and it helped them refocus on problems (19%).

- What are your feelings about, or what have you gained from this class? Why?

All of the participants had positive attitudes toward the class. The primary reasons were that their critical-thinking skills and abilities had greatly improved (48%); they had benefited substantially from group discussions (17%); and they had become better able to think rationally when faced with problems (10%). However, a few participants responded that there were too many assignments and that the discussions were too long (10%).

DISCUSSION

Effects of integrating collaborative BPL and blended learning

In conducting this research, it was somewhat difficult to get the control group to finish all of the same tests that the experimental group was administered. Therefore, the participants' improvements in critical-thinking skills were evaluated by comparing their scores on the pretest with those on the posttest. Although a pretest-posttest control group design is generally considered superior to a before-and-after design, the before-and-after design is still commonly deemed acceptable, particularly when a control group is difficult to get. To compensate for the shortcoming of the before-and-after design, this study employed 2 complementary instruments: the SB-CTT and the reflection questionnaire. The results of the Repeated Measure Analyses of Variance as well as the content analysis of the participants' responses in the reflection questionnaire fully supported the two hypotheses put forth in this study. In other words, all of the evidence indicates that integrating collaborative PBL and blended learning enhanced the preservice teachers' professional development in critical-thinking instruction.

This study employed two tests (the CTT-II and the SB-CTT) to evaluate whether or not the participants improved their critical-thinking skills during the 18-week period of experimental instruction. The analytical results indicate that the participants scored significantly higher on the posttest than on the pretest of both the CTT-II and the SB-CTT. These findings determined that the experimental instruction in this study was effective in improving the preservice teachers' critical-thinking skills. Important to note, 97% of the participants reported that the instructional design improved their critical-thinking skills and the most important reason for this was that the instructional design increased the number of opportunities they had for online discussions. Commonly cited too was the fact that the online discussions increased their opportunities to practice their critical-thinking skills. It is also worth noting that the participants were completely supportive of the use of collaborative PBL and stated that the approach helped them connect theory and practice, while serving as a stimulus to multi-perspective thinking. In their own words, such learning "made sense" to them. The participants also strongly supported the use of learning contracts, concept mapping, and the role plays during the problem-solving process.

The instructional design in this study—collaborative PBL in a blended learning environment—incorporated the case study approach as well as the strategies of cooperative learning, discussion, concept mapping, role play, observational learning, guided practice, and self-reflection. The findings are in line with earlier findings and suggestions (e.g. DaRosa, et al., 2001; Halpern, 1998; Kamin et al., 2003; Mackinnon, 2006; Semerci, 2006; Tiwari et al., 2006) that PBL is an effective approach for improving critical thinking. Halpern (1998) explained that problems and arguments can indeed enhance the transcontextual transfer of critical-thinking skills. And, DeRoche (2006) recently suggests that PBL provides students with loosely structured real-life problems and that as students go about trying to solve a problem, they are guided by the problem itself and must continually seek, find, organize, and evaluate information.

With regard to the learning processes involved in collaborative PBL, Lee and Kim (2005) point out that students are required to: (1) explore and represent a problem; (2) identify what they already know about the problem; (3) make clear what they do not know; (4) identify their goals and make an action plan; (5) collect relevant information; (6) discuss the information collected; (7) apply their prerequisite knowledge to the problem; and (8) review the above steps. However, they point out that the sequences can differ more or less in accordance with students' newly-formed ideas. Generally, this study closely followed these procedures. To help the participants define their goals and make an action plan, they were asked to construct a group contract; to facilitate their discussion and problem-solving skills, they were asked to make a concept map; and to encourage them to review the learning process, they were asked to make a group portfolio. The extent to which PBL served to facilitate the preservice teachers' critical-thinking skills may very well, at least partially, be attributed to these supplementary strategies.

The findings in this study also lend support to the argument that case studies are invaluable in teacher education (Carter & Unklesbay, 1989). In addition, the results support the position that concept mapping contributes to self-reflection, knowledge construction, and the identification of causal relationships, all of which are essential for good critical thinking. Based on Ausubel's assimilation theory of cognitive learning, concept mapping requires that cognitive structures be organized hierarchically, with new concepts being subsumed under more inclusive ones. When learners arrange newly-acquired knowledge in such a ranked

fashion and explore the possible linkages among various notions, meaningful learning occurs (as cited in Novak & Gowin, 1984). Moreover, in constructing a concept map, learners' self-reflection and cognitive reasoning skills are sharpened since they are organizing the concepts meaningfully, making connections among them and deciding on their causal relationships.

E-learning is moving towards providing an environment that facilitates broad-based content creation, sharing, reuse, and distribution, rather than just focusing on replacing information that is traditionally learned in a common classroom setting. Soft skills are emerging as the current and immediate future direction of e-learning (Tastle, White, & Shackleton, 2005). Skills in problem-solving and critical-thinking are certainly among these soft skills. According to multichannel communication theory, humans have several channels through which data are communicated. If information is presented by way of two or more of these channels, then there is additional reinforcement and greater retention, thereby improving learning (Bagui, 1998). Accordingly, this study employed multiple methods to develop preservice teachers' critical-thinking skills. First, the experimental instruction was conducted via the integration of PBL, e-learning, and classroom teaching. Second, PBL was employed by combining the case study approach and several different strategies, such as a learning contract, concept maps, role plays, and self-reflection.

As Mortera-Gutiérrez (2006) puts it, the combination of face-to-face instruction and communication technology in a blended learning environment creates a myriad of educational possibilities that reflect a certain pedagogical richness. To have technological media supporting course activities and assignments in a blended learning course allows students to have greater control of their goals. However, the aim of using blended learning approaches is to find a harmonious balance between online access to knowledge and face-to-face human interaction (Osguthorpe & Graham, 2003). The findings in this study indicate that such a harmonious balance was reached in this study.

Mechanisms that contribute to instructional effectiveness

Problem-based learning

In this study, the participants were unanimous in their opinion that the PBL in this study, with authentic case studies and concept mapping, contributed to their personal improvement in critical thinking. In addition, 94% held a positive attitude toward the use of role plays and 68% toward learning contracts. An analysis of the reasons for their positive attitudes suggests that the PBL applied in this study triggered preservice teachers' motivation and encouraged discussion, interaction, practice, and multiple-perspective thinking, in turn improving their critical-thinking skills.

As a general rule, PBL immerses learners into an authentic context with ill-structured problems (Simons et al., 2004), and they are assigned to groups to solve these problems; each participant therefore learns how to apply his/her related knowledge and strategies to solve problems (Ochoa & Gottschall, 2004). And, as critical thinking is usually used in problem-solving, PBL can be effective in improving critical-thinking skills.

Guided practices

Participants in this study were given opportunities for guided practices when they were asked to decide on a case for PBL, to form a learning community via group discussions and by making group contracts, to visualize their arguments via concept mapping, to act out their arguments via role plays, and to self-reflect via creating a group portfolio of the PBL process. What the findings suggest is that the preservice teachers' improvements in critical-thinking skills are rooted in adequate opportunities to practice critical-thinking skills. Thus, it can be concluded that guided practices contribute to mastering critical-thinking skills.

Discussion and sharing

During the process of developing their critical-thinking skills, learners must be active participants on the grounds that their success is contingent on the quality of interactions, discussions, and cooperation. As Eggen and Kauchak (2001) suggest, for students to develop their critical-thinking skills, a classroom environment that values different perspectives and a great deal of discussion is essential. This was reflected in the reflection questions in which many participants stated that discussions, especially those online, were a great contributor to the improvement in their critical-thinking skills.

Bastiaens and Martens (2000) note that web-based learning provides users with opportunities to express their ideas and that this stimulates thinking through interpersonal interactions. It is pertinent here that Eastmond (1995) also argued that learners should be provided opportunities to interact and reflect and that such learning occurs when an instructor merges online discussions and learning methods in computer-mediated communications. This study confirms the importance of discussion and sharing in e-learning.

Observational learning

To provide the participants with opportunities for peer modeling and observational learning in this study, the groups were asked to hand in all assignments to the e-learning interface, and these assignments were always available for all participants to read; moreover, a group presentation on instructional design and a teaching demonstration were required of all groups. The findings in this study indicate that reading other groups' assignments online contributed to self-reflection, provided extra practice with critical-thinking skills, and encouraged the generation of novel ideas. Such skills are central characteristics of good critical thinking (Paul & Elder, 2001), and observational learning clearly contributes to the cultivation of these skills.

Self-reflection

All of the participants in this study agreed that the inclusion of blended learning increased the extent of their reflection about their attitudes toward their skill in and teaching of critical thinking; it is noteworthy that such effects are generally derived from discussions, especially those online. This finding supports Maher and Jacob's (2006) claim that the use of computer-mediated communications facilitates peer interactions and the reflective consideration of instructional practices.

A reflective mind is the hallmark of critical thinking (Schroyens, 2005). Titone, Sherman, and Palmer (1998) maintained that providing feedback is an effective method of increasing mindful learning, which further contributes to nurturing reflective practices. The instructional

design of this study simultaneously incorporated the use of "peer feedback" and "teacher feedback". Whereas peer feedback was mainly provided through online discussions, teacher feedback was provided through classroom interactions. This study provided additional feedback through the test results, all in an effort to increase participants' self-awareness and self-reflection.

CONCLUSIONS AND SUGGESTIONS

Cultivating critical thinkers has been one of the most important educational goals of secondary school education throughout the past decade. The need for secondary school teachers' professional development in teaching critical thinking cannot be overstated. In that collaborative PBL provides a natural framework for professional development and blended learning allows participants to develop more critical and reflective attitudes toward learning goals, this study integrated collaborative PBL with blended learning, and based on this framework, provided preservice teachers with experimental instruction. The findings from this study are convincing: preservice teachers' critical-thinking skills improved considerably in this training program. The mechanisms that facilitated such effects were mainly problem-based learning, guided practice, discussion and sharing, observational learning, and self-reflection.

Due to the difficulty in getting a control group, this study employed a before-and-after design. Future studies should try to use a pretest-posttest control group design to confirm the instructional benefits found in this study. Moreover, to maximize the effects of blended learning, teachers need to determine how to reach a perfect balance between online learning and in-class learning and learn how to employ different kinds of online learning strategies.

ACKNOWLEDGMENT

The author would like to thank the National Science Council of the Republic of China, Taiwan, for financially supporting this research under Project No. NSC94-2520-S-004-001.

REFERENCES

Albion, P., & Gibson, I. (2000). Problem-based learning as a multimedia design framework in teacher education. *Journal of Technology and Teacher Education*, *8*(4), 315-326.

Alvermann, D. E. (1986). Graphic organizers: Cueing devices for comprehending and remembering main ideas. In J. F. Baumann (Ed.), *Teaching main idea comprehension* (pp. 210-226). Newark, DE: International Reading Association.

Bagui, S. (1998). Reasons for increased learning using multimedia. *Journal of Educational Multimedia and Hypermedia*, *7*(1), 3-18.

Bailin, S., Case, R., Coombs, J. R., & Daniels, L. B. (1999). Common misconceptions of critical thinking. *Journal of Curriculum Studies, 31*(3), 269-283.

Bastiaens, T. J., & Martens, R. L. (2000).Conditions for web-based learning with real events. In B. Abbey (Ed.), *Instructional and cognitive impacts of web-based education* (pp.1-31). London: Idea Group Publishing.

Beaudin, B. P. (1999). *Keeping on-line asynchronous discussion on topic*. Retrieved April 2, 2007 from WWW: http://www.aln.org/publications/jaln/v3n2/v3n2_beaudin.asp

Boud, D. (1985). Problem-based learning in perspective. In D. Boud (Ed.), *Problem-based learning in education for the professions* (pp. 13-18). Sydney: Higher Education Research Society of Australasia.

Browne, M. N., & Meuti, M. D. (1999). Teaching how to teach critical thinking. *College Student Journal, 33*(2), 162–170.

Carmen, C., & Kurubacak, G. (2002). The use of the internet to teach critical thinking. *Society for Information Technology and Teacher Education International Conference, 2002*(1), 2504-2505.

Carter, K., & Unklesbay, R. (1989). Cases in teaching and law. *Journal of Curriculum Studies, 21*(6), 527-536.

DaRosa, D. A., ÓSullivan, P. S., Younger, M., & Deterding, R. (2001). Measuring critical thinking in problem-based learning discourse. *Teaching and Learning in Medicine, 13, 27-35.*

Delisle, R. (1997). *How to use problem-based learning in the classroom.* Alexlandria, VA: Association for Supervision and Curriculum Development.

DeRoche, S. J. K. (2006). An adventure in problem-based learning. *Phi Delta Kappan, 87*(9), 705-708

Eastmond, D. V. (1995). *Alone but together: Adult distance study through computer conferencing.* Cresskill, NJ: Hampton Press.

Eggen, P. D., & Kauchhak, D.P. (2001). *Educational Psychology: Windows on the classroom* (5th ed.). Upper Saddle River, N.J: Merrill Prentice Hall.

Ellis, T. J. (2001). Multimedia enhanced educational products as a tool to promote critical thinking in adult students. *Journal of Educational Multimedia and Hypermedia, 10*(2), 107-124.

Engel, C.E. (1997). Not just a method but a way of learning. In D. Boud and G.E. Feletti (Eds.), *The challenge of problem-based learning* (pp. 17-27). London: Kogan Page Limited.

Ennis, R. H., Millman, J., & Tomko, T. N. (1985). *Cornell Critical Thinking Tests, Level X & Level Z--Manual*. CA: Midwest Publications.

Gadzella, B. M., & Masten, W. G. (1998). Critical thinking and learning processes for students in two major fields. *Journal of Instructional Psychology, 25*(4), 256-261.

Garrison, D. R., Anderson, T., & Archer, W. (2001). Critical thinking, cognitive presence, and computer conferencing in distance education. *American Journal of Distance Education, 15*(1), 7-23.

Gerber, M.M., English, J., & Singer, G.S. (1999). Bridging between craft and academic knowledge: A computer-supported, problem-based learning model for professional preparation in special education. *Teacher Education and Special Education, 22*, 100-113.

Giancarlo, C. A., & Facione, P. A (2001). A look across four years at the disposition toward critical thinking among undergraduate students. *Journal of General Education, 50*(1), 29-55.

Halpern, D. F. (1998). Teaching critical thinking for transfer across domains, dispositions, skills, structure training, and metacognitive monitoring. *American Psychologist, 53*(4), 449-455.

Halpern, D. F. (2003). *Knowledge and thought: An introduction to critical thinking* (4th ed.). Hillsdale, NJ: Lawrence Erlbaum.

Harris, J. C., & Eleser, C. (1997). Developmental critical thinking: Melding two imperatives. *Journal of Developmental Education, 21*(1), 12-19.

Hughes, M., & Daykin, N. (2002). Towards constructivism: Investigating students' perceptions and learning as a result of using an online environment. *Innovations in Education and Teaching International*, 39(3), 217-224.

Jorden, E. A., & Porath, M.J. (2006). *Educational psychology: A problem-based approach*. Boston, MA: Allyn and Bacon.

Kamin, C., ÓSullivan, P., Deterding, R., & Younger, M. (2003). A comparison of critical thinking in groups of third-year medical students in text, video, and virtual PBL case modalities. *Academic Medicine, 78,* 204-211.

Kumta, S. M., Tasng, P. L., Hung, L. K., & Cheng, J. C. Y. (2003). Fostering critical-thinking skills through a web-based tutorial progamme for final year medical students—a randomized controlled study. *Journal of Educational Multimedia and Hypermedia, 12*(3), 267-273.

Lee, M., & Kim, D. (2005). The effects of the collaborative representation supporting tool on problem-solving processes and outcomes in web-based collaborative problem-based learning environments. *Journal of Interactive Learning Research, 16*(3), 273-293.

Littleton, K., & Hakkinen, P. (1999). Learning together: Understanding the process of computer based collaborative learning. In P. Dillenbourg (Ed.), *Collaborative learning: Cognitive and computational approaches*. New York, NY: Pergamon.

Mackinnon, G. R. (2006). Contentious issues in science education: Building critical-thinking patterns through two-dimensional concept mapping. *Journal of Educational Multimedia and Hypermedia, 15*(4), 433-445.

Maher, M., & Jacob, E. (2006). Peer computer conferencing to support teachers' reflection during action research. *Journal of Technology and Teacher Education, 14* (1), 127-150.

Mayo, P., Donnelly, M. B., Nash, P. P., & Schwartz, R. W. (1993). Student perceptions of tutor effectiveness in problem based surgery clerkship. *Teaching and Learning in Medicine, 5*(4), 227-233.

McCarthy-Tucker, S. N. (2000). Teaching style, philosophical orientation and the transmission of critical thinking skills in the U.S. public schools. *Korean Journal of Thinking and Problem Solving, 10*(1), 69-77.

Merseth, K. K., & Lacey, C. A. (1993). Weaving stronger fabric: The pedagogical promise of hypermedia and case methods in teacher education. *Teaching and Teacher Education, 9*(3), 283-299.

Moore, D. W., & Readence, J. E. (1984). A quantitative and qualitative review of graphic organizer research. *Journal of Educational Research, 78*(1)*,* 11-17.

Mortera-Gutiérrez, F. (2006). Faculty best practices using blended learning in e-learning and face-to-face instruction. *International Journal on E-learning, 5*(3), 313-337.

Nelson, T., & Oliver, W. (2004). Maximizing critical thinking skills with technology. In P. Kommers and G. Richards (Eds.), *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications, 2004,* 3982-3986.

Novak, J. D. (1984). Application of advances in learning theory and philosophy of science to the improvement of chemistry teaching. *The Journal of Chemical Education, 61*(7), 607-612.

Novak, J. D., & Gowim, D. B. (1984). *Learning how to learn.* Cambridge, England: Cambridge University Press.

Ochoa, T. A., & Gottschall, H. (2004). Group Participation and Satisfaction: Results from a PBL Computer-Supported Module. *Journal of Educational Multimedia and Hypermedia, 13*(1), 73-91.

Ochoa, T. A., Gerber, M. M., Leafstedt, J. M., Hough, S., Kyle, S., Rogers-Adkinson, D., & Kumar, P. (2001). Web technology as a teaching tool: A multicultural special education case. *Journal of International Forum of Educational Technology & Society, 4*(1), 50-60.

Osguthorpe, R. T., & Graham, C. R. (2003). Blended learning environments: Definitions and directions. *The Quarterly Review of Distance Education, 4*(3), 227-233

Paul, R., & Elder, L. (2001). *Critical thinking: Tools for taking charge of your learning and your life.* Upper Saddle River, NJ: Prentice Hall.

Ram, P., Ram, A. & Sprague, C. (2004). A web-based system to bring PBL into your classroom. *Proceedings of Society for Information Technology and Teacher Education International Conference, 2004,* 3007-3012.

Raymond, A. M. (1997). The use of concept mapping in qualitative research: A multiple case study in mathematic education. *Focuses of Learning Problems in Mathematics, 19*(3), 1-28.

Rich, D (2001). E-learning: A new way to develop employees. *Electronic Business, 27*(8), 20.

Rossman, M. H. (1999). *Successful online teaching using an asynchronous learner discussion forum*. Retrieved June 6, 2007, from http://www.aln.org/publications/jaln/v3n2/v3n2_rossman.asp

Savery, J. R., & Duffy, T. M. (1995). Problem-based learning: An instructional model and its constructivist framework. *Educational Technology*, *35*(5), 31-38.

Schroyens, W, (2005). Knowledge and thought: An introduction to critical thinking. *Experimental Psychology, 52*(2), 163-164.

Semerci, N. (2006). The effect of problem-based learning on the critical thinking of students in the intellectual and ethical development unit. *Social Behavior and Personality, 34,* 1127-1136.

Simons, K., Klein, J., & Brush, T. (2004). *Instructional strategies utilized during the implementation of a hypermedia, problem-based learning environment: A case study*. *Journal of Interactive Learning Research, 15*(3), 213-233.

Stewart, J. H. (1984). The representation of knowledge: Curricular and instructional implications for science teaching. In C. D. Holley and D. F. Dansereau (Eds.), *Spatial learning strategies: Techniques, applications, and related issues* (pp. 235-253). San Diego, CA: Academic Press.

Tastle, W. J., White, B. A., & Shackleton, P. (2005). E-learning in higher education: The challenge, effort, and return in investment. *International Journal on E-learning, 4*(2), 241-251.

Titone, C., Sherman, S., & Palmer, R. (1998). Cultivating student teachers' dispositions and ability to construct knowledge. *Action in Teacher Education, 19* (4), 76-87.

Tiwari, A., Lai, P., So, M., & Yuen, K. (2006). A comparison of the effects of problem-based learning and lecturing on the development of students' critical thinking. *Medical Education, 40, 547-554.*

Watson, G., & Glaser, E. M. (1980). *Watson-Glaser Critical Thinking Appraisal*. San Antonio, TX: Psychological Corp.

Yeh, Y. (2005). *Integrating e-learning into a teacher education curriculum: Its effects on improving preservice teachers' ability to teach critical thinking.* Taipei: National Council of Science. (NSC93-2520-S-004-002)