Effects of an online problem based learning course on content knowledge acquisition and critical thinking skills

Serkan Şendağ a,*, H. Ferhan Odabaşı b,1

a Anadolu University, Graduate School of Educational Sciences, 26470 Eskisehir, Turkey
b Anadolu University, Faculty of Education, Department of Computer Education and Instructional Technologies, 26470 Eskisehir, Turkey

1 Corresponding author. Tel.: +90 (222) 3350580x3519; fax: +90 (222) 335 0579.
E-mail addresses: serkansendag@gmail.com (S. Şendağ), fodabasi@anadolu.edu.tr (H. Ferhan Odabaşı).

1 Tel.: +90 (222) 3350580x3519; fax: +90 (222) 335 0579.

1. Introduction

Today's working conditions have required fundamental changes in the profiles of work power, which basically stemmed from the rapid change and transformation in the nature of information. For societies to survive in this competitive world, they need to equip individuals with skills to conduct research, use and transform information, think critically and reflectively, and make higher order decisions. In addition, technological changes along with the changes in the workplace have made critical thinking abilities more important than ever before. In this regard, the instruction designed to assist students' critical thinking focuses on skills that are applicable across different domains of knowledge and the disposition to use these skills (Halpern, 1999). The report of the National Commission on Excellence in Education, A Nation at Risk (1983) sounded an alarm regarding insufficient and ineffective attempts to foster higher order thinking skills in schools including critical thinking and problem solving. The Secretary's Commission on Achieving Necessary Skills (1991) regarded higher order thinking competencies as complementary for productive workplaces including critical thinking, decision making, problem solving and reasoning. In short, the ability to understand and use information is emphasized rather than merely possessing it (Richardson, 2003). In this respect, it is crucial for teacher candidates to have these higher order thinking and problem solving skills along with the ability to cooperate and work effectively within a team. Thus, integration of constructivist approaches such as problem based learning (PBL) into the instructional endeavors carries utmost importance (Yaşar, 1998), as constructivism represents how people deal with real-life problems in society by working with peers to make effective thoughtful decisions, take the initiative and solve problems (Jonassen, 1997).

1.1. Problem based learning (PBL)

Different definitions of PBL in the literature address three basic principles to differentiate PBL settings from those that are not implementing the PBL. First, it is necessary to have a problem to trigger learning. Second, PBL is not an instructional technique in isolation; rather, it is a holistic approach involving interaction of several learning approaches and methods. Third, PBL is almost always...
student-centered. These principles offer the opportunities to actively process information, trigger prior knowledge, have a meaningful content, and research and organize information (Kocaman, Okumus, & Bahar, 2003).

PBL is based on several learning approaches. For instance, Schmidt (1993) maintains that PBL is based on information processing theory, in which learning requires learners to participate actively in the process of retrieving, constructing, and using information; and relate new information with their prior knowledge. Norman and Schmidt (2000) explain PBL through a constructivist viewpoint where information is acquired and general principles are learnt during problem solving practices to be used for similar future problems. Hoffman and Ritchie (1997) consider PBL as ‘a student-centered strategy that has significant contextualized, real-world, ill-structured situations while providing resources, guidance, instruction and opportunities for reflection to learners as they develop content knowledge and problem solving skills’ (p. 97). As indicated in the definition, students have an active role in solving a real-life problem. Learning occurs when learners reflect on their learning, while instructors serve as guides and facilitators. In this respect, instructors do never offer the ready response for a problem (Barrows, 1996; Gallagher, 1997; Stepien, Gallagher, & Workman, 1993). They have a direct influence on the success of the process. More specifically, they exert the direct influence to attract students’ attention whereas they have an indirect influence in increasing achievement (Dolmans, Wolfhagen, & Schmidt, 1994). Proficiency in providing guidance carries utmost importance in this regard. While providing guidance and facilitating the process, they are supposed to sustain the functionality of the group and lead the group to learning objectives (Abacıoğlu, 1998).

PBL activities are designed in a way that is possible for instructors to offer guidance for ill-structured and complicated problems (Gallagher, Stepien, & Rosenthal, 1992). Such problems require learners to adopt higher order thinking skills such as critical thinking. Barrows (1985) summarizes the features of ill-structured problems. First of all, sufficient information to understand the problem is more than the information provided in the problem situation. Second, new information about the problem situation can change the definition of the problem. Third, different perspectives are necessary to interpret information. Finally, there is no definite and single solution for the problem.

Ill-structured problems are similar to those that learners are supposed to solve in their real lives in which the definition of the problem is not clear and some features of the problem are not provided. Particularly the information directing learners to the solution is not provided within the problem situation. Since they are not limited to common classroom situations, the solutions are not predictable. Moreover, resorting to different disciplines may be necessary to solve the problem. As they are similar to real-life problems, student motivation is generally high (Jonassen, 1997).

It has been maintained in the literature that PBL positively influence learning outcomes along with learners’ higher order thinking skills such as creative thinking, problem solving, logical thinking and decision making. For instance, Elshafei (1999) compared the Calculus achievement levels of second graders in five different high schools and 15 different classes where PBL and traditional instructional methods were implemented. Findings indicated that students in PBL settings did prefer this method and had higher levels of achievement. In addition, it was revealed that students in PBL settings had better solutions for given problems in comparison to those who were in traditional classroom settings. Kaptan and Korkmaz (2000) investigated the influence of PBL on problem solving skills and self-efficacy levels of inservice teachers. Findings revealed that the experimental group which was exposed to fundamental science activities through PBL had higher self-efficacy and logical thinking scores than the control group. Deveci (2002) explored the influences of PBL in social science classes on students’ attitudes, achievement levels and retention grades all of which were found to be higher in PBL settings. Yaman and Yalçın (2005) investigated the effects of PBL on creative thinking skills of teacher training students through a pretest–posttest control group design, which revealed that the PBL group had higher scores in creative thinking measures in comparison to the control group. Similar to above studies, several researchers claimed that PBL had a positive influence on problem solving and critical thinking skills (Gallagher, 1997; Hmelo, 1998).

1.2. Critical thinking skills (CTS)

Critical thinking has been the focus of several current implementations in educational settings. Thinking is based on relating and drawing conclusions on notions and events, and involves a variety of different cognitive processes such as implicating, problem solving, examining, reflecting and criticizing. Thinking begins with a physical or psychological inconvenience stemming from lacking the solution for a problem whose solution becomes the objective for an individual. Higher order thinking skills like critical thinking, creative thinking and problem solving are considered necessary skills for 21st-century individuals. Thus, it is necessary to examine these notions objectively, scrutinize on the contents of these skills, and elaborate on the ways to equip individuals with such skills. Problem solving involves cognitive, sensory and psychomotor domains which helps instructors to resort to a large variety of contexts and materials. However, it was maintained that the most valid and reliable way to equip individuals with problem solving skills is to integrate it with creative thinking and decision making (Kalaycı, 2001).

As a non-controversial claim, critical thinking entails awareness of one’s own thinking and reflection on the thinking of the self and others. In this regard, metacognition is defined as thinking about thinking, a skill originating early in life when children first become aware of the mind. However, metacognition does not always develop to the extent that we would like (Kuhn & Dean, 2004). The construct of metacognition can be examined within a developmental framework during which the metacognitive skills become more powerful and effective gradually as they operate increasingly under individuals’ conscious control. Thus, improving metacognitive awareness of what to believe and how to know; and employing metacognitive control on information processing strategies are important developmental and educational goals.

Critical thinking involves critical implication and discussion, which has a crucial role in activating problem solving and decision making processes (Chaffee, 1994). Critical thinking is a constructivist analysis process to examine what is going on in our environments. This analysis system can be used to define problems, take actions towards an aim, make decisions and conduct retrospective evaluations. In order to define, describe, measure and evaluate the critical thinking process, it is necessary to understand indicators of CTS. Several researchers provided the literature with comprehensive classifications in this regard. For instance, the Watson–Glaser classification of CTS involves defining a problem, determining possible solutions and strong assumptions, drawing valid conclusions regarding the solution and evaluation these conclusions (Demirtaşlı-Çıkrıkçı, 1996; Kaya, 1997). Such skills are

- Inference: Defining a problem involves selecting the most appropriate information piece leading to the solution. Making decisions regarding the credibility of assumptions based on the information provided within a text is an inference process.
critical thinking is a comprehensive thinking way involving analysis, synthesis, interpretation, evaluation and noticing assumptions. Thus, making use of CTS in instructional practices in teacher training helps instructors to equip learners with significant 21st-century skills.

1.3. PBL in online environments

As a result of constructivism, a transition from teaching to learning and from teacher-centered approaches to learner-centered approaches has been experienced. Online learning practices usually follow constructivist perspectives and make use of the Internet to facilitate personalized learning regardless of time and space boundaries. Moreover, as online learning environments are flexible, attractive and interactive, it is more convenient to implement constructivist and PBL practices through online learning tools.

Studies on the use of PBL in online learning environments generally described the implementation process. For instance, Cho and Jonassen (2002) examined students' use of online discussion supports to back up their discussions on problem situations. It was revealed that the influence of the discussion support varied according to the type of the problem. Students solving ill-structured problems delved into more intense discussions. A significant relationship between discussion and problem solving was found during ill-structured problems. Finally, it was revealed that students meaningfully transferred what they had learnt from online discussion facilities to their actual discussions during problem solving.

Donnelly (2006) conducted a case study where online PBL techniques were integrated into a face-to-face setting. Instructors, librarians and technical support staff from different universities in Ireland participated in a graduate course for ten weeks. Social interaction in PBL was sustained through both face-to-face and online discussion groups. It was revealed that group activities played the key role in the success of the process. Participants appreciated the fact that the instructor's role was explained clearly at the beginning of the process as facilitator, guide and discussion moderator. It was also indicated that sustaining the student–content and student–student interaction carried utmost importance.

McLinden, McCall, Hinton, Weston, and Douglas (2006) conducted a two-phase research project to develop online problem-based resources for the professional development of teachers of children with visual impairment. First, they designed, developed, implemented and evaluated an online flexible instructional resource based on PBL principles. Of 90 professionals attending an online professional development course, ten voluntarily participated in the study. In the second phase, they explored how the pilot online PBL resources develop in the first phase can effectively be embedded into the restructured programme of the study. Findings indicated that participants accessed and used online resources quite comfortably. It was implicated that online PBL applications should support access to information and collaborative learning, and sustain interaction among learners. It was also indicated that online PBL environments can be an effective tool to provide special education professionals with in-service training.

An (2006) worked out several instructional design principles for instructors, practitioners and instructional designers regarding the design and development of online collaborative PBL environments. It was suggested that only online courses with appropriate collaboration characteristics should make use of the PBL. More specifically, if the scheduling of the course makes it hard to implement collaborative activities, the PBL need not be used. It was suggested that problems should be relevant to students' current or future life experiences. In addition, the nature of the problem situations, number of solutions and problem contexts should be taken into account along with technological infrastructure while arranging the working groups.

Some studies compared online PBL environments with other methods. Özdemir (2005) maintained that students in a collaborative PBL environment outperformed those who were in an individual PBL environment in terms of critical thinking scores. It has been observed that, in online PBL studies, individual differences like cognitive flexibility has also been investigated in addition to inquiries on different methods. Batting (1979) defines cognitive flexibility as the skill to use the most effective learning strategy for a specific content or the skill to determine problem solving steps for a certain problem. More specifically, cognitive flexibility can be defined as (a) alternative learning strategies and problem solving skills existent in learners' repertoire, (b) the ability to choose from these alternative learning strategies and problem solving skills effectively. In this regard, Alper (2003) investigated the effect of cognitive flexibility in online PBL on student achievement levels and attitudes. Thirty high school students participated in the study. Students were divided into three categories in terms of their cognitive flexibility: low-, medium- and high-level; and their achievement levels were measured through the Ren Test. Findings indicated that online PBL application increased students' achievement levels and retention scores. In addition, it was revealed that the level of cognitive flexibility did not have an effect on student achievement, attitude and retention scores. Dennis (2003) conducted an experimental study with 34 medical science students to compare face-to-face and online PBL classrooms. Findings indicated that the groups did not differ in terms of achievement, but the online group spent significantly more time for activities.

1.4. Problem statement

A review of literature indicated that PBL had positive effects on increasing content knowledge (Candela, 1999; Korucu, 2007), while some studies suggested that it did not have a significant effect on content knowledge acquisition (Alper, 2003; Deveci, 2002; Elshafei et al., 1999). Such controversial findings could stem from the followings:

- Different constructs and skills related to achievement has been examined in different studies.
- Online learning tools have a unique motivating effect.
- PBL has different effects on learners from different age-levels.
- Individual differences like cognitive flexibility effects the findings.
In addition, some studies revealed that PBL was effective in increasing critical thinking skills (Albanese & Mitchell, 1993; Vernon & Blake, 1993) which could stem from the followings:

- Structured problem situations in online PBL environments urge learners to think deeper, question, discuss and conduct research.
- Students reason about the things they learn and the things they need to learn.
- The organization of information resources in online PBL environments helps learners to individualize the content.
- The new information organization helps learners assume a new role as initiative takers and guides.

The studies examined reveal that implementing PBL in online environments has gained increasing interest particularly in higher education institutions. Training teachers who have critical thinking, problem solving, collaboration and networking skills is a must in the current century. In this respect, implementing methods like PBL in teacher training settings can serve as an example of using alternative methods in online environments. In addition, implementing online collaborative PBL helps increasing technology use and higher order thinking skills. However, implementation of online instruction should not be realized as the transfer of face-to-face activities to online environments. It seems that the potential of online environments to encourage participation and facilitate student–student, student–instructor, student–technology and student–content interaction is not benefited sufficiently. This situation constituted the problem statement of the current study. More specifically, the current study aimed to compare online PBL and online instructor-led learning in terms of their influence on students’ content knowledge acquisition and critical thinking skills. Following research questions were addressed:

1. Do the content knowledge test scores of the online PBL group increase more significantly than the scores of the online instructor-led group?
2. Do the CTS scores of the online PBL group increase more significantly than the scores of the online instructor-led group?

2. Methods and procedures

In the current study, the pretest–posttest control group design was implemented to investigate the effects of the independent variable (i.e. online PBL vs. instructor-led) on dependent variables (i.e. content knowledge and CTS scores). Groups were randomly assigned to the levels of the independent variable to realize a true experiment (Karasar, 2000).

2.1. Subjects

The subjects included 40 of the students who attended Computer II course in 2008 spring at the Department of Primary School Mathematics Teaching in Anadolu University Education Faculty. They were randomly assigned to the experiment (16 females and 4 males) and the control group (15 females and 5 males). Before the assignment, matched pairs were created based on subjects' prior content knowledge, prior CTS scores, final grades from the Computer I course, Internet use hours per week, and gender. Then, member of each pair was randomly assigned to the experiment (online PBL) and control (online instructor-led) groups. The courses in each group were led by the same instructor who is experienced in both online teaching and PBL. The instructor had eight years of experience on online teaching, and three years of experience on PBL.

2.2. Instruments

The Turkish version of the Watson–Glaser critical thinking skills test, which was adapted to Turkish context by Çıkrıkçı (1992) was used along with a 40-item multiple choice content knowledge acquisition test developed by the researchers. Both instruments were implemented before and after the treatment.

The content knowledge test aimed to measure learning outcomes of each content unit through at least one question. Items at the levels of knowledge, comprehension and application were developed and validated by an expert panel consisting of five instructors at the Department of Computer Education and Instructional Technologies (CEIT). After suggested revisions were made, researchers resorted to test–retest method to measure reliability. Since the literature suggested that the piloting should be made with at least 30 participants (Tavşancıl, 2002), 37 junior students enrolled at the CEIT Department and 30 sophomore students enrolled at the Department of English Language Teaching were administered the test twice with a two-week interval. The reliability coefficient was found sufficient for further administration \( r = 0.77 \) as suggested by Özçelik (1981).

CTS test consisted of 100 items covering five constructs, 20 of which addressing the construct of inference, 16 items addressing recognition of assumptions, 25 items addressing deduction, 24 items addressing interpretation and 15 items addressing the evaluation of arguments. The adaptation of the test to Turkish context with a reference to necessary reliability and validity measures was realized by Çıkrıkçı in 1992 through administering the tool to high school students. The tool was also administered to undergraduate freshman students in 1996. Relationships among the constructs were between .21 and .50 in the high school administration, and between .20 and .47 in the freshman administration. The relationship of the constructs with the total score was between .56 and .79 in the high school administration. The reliability coefficient of the freshman administration was .63 (Çıkrıkçı, 1993; Demir Taşlı-Çıkrıkçı et al., 1996). Kaya (1997) administered the test to senior students and found the relationships among constructs between .24 and .73. In addition, the reliability of the whole instrument was found as .73. Based on these indices, the test was found appropriate for the current study.

2.3. Procedure

2.3.1. Course selection

The treatment was implemented during two units covered in the Computer II course, which were ‘Computers in Education’ and ‘Computer Assisted Instruction’ since these subjects were mostly covered theoretically rather than practically which led to learning outcomes at
the knowledge level. Students were supposed to choose commercial software for evaluation purposes in these units. However, these contents were found crucial for teacher trainees as these helped trainees to select the most appropriate software and integrate current technologies to their class practices. In this regard, it was considered necessary for teacher trainees to have authentic learning experiences with real social interaction patterns in order for them to implement higher order evaluation skills, develop creative solutions for problems and realize in-depth thinking regarding the evaluation and use of information and communication technologies. The course was offered in a 50% theoretical and 50% practical fashion. Particularly the theoretical part was implemented through traditional lecture without sufficient social interaction among students, which prevented students from internalizing contents and transforming their content knowledge to new and unique situations.

The practical part of the course had similar problems. Students were supposed to observe the instructor and do what was asked afterwards. These practices improved their technology knowledge rather than their technology integration skills, which was far from what is expected from 21st-century teachers. Objectives of the course involved skills like solving new technology integration problems, conducting research, transforming information, and delivering their messages correctly. If such skills were not attained properly, students would need a facilitator or guide in future as well to interpret new technologies for them, which can be impossible during in-service teaching. In this regard, researchers decided to implement online PBL in the Computer II course in a way that students would be able to resort to their higher order thinking skills, take responsibility for their own learning, have authentic learning experiences, conduct research and think reflectively.

2.3.2. The online platform

In order to implement online activities, MOODLE was used. MOODLE is a course management system freely accessible on the Internet, which could work effectively with both Windows and Linux, resorted to MySQL database and employed PHP programming techniques. The program was installed on a 5 GB-disk space by the researcher using the domain name www.egitimonline.org. The Computer II course was provided on this website to users who were able to benefit from several online tools such as chat, discussion forum, databases, file download and upload, and e-mail services.

Computer II-A was available for the experiment group who were exposed to online PBL activities whereas Computer II-B was created for the control group who were exposed to online instructor-led activities. Problem scenarios for the experiment group, course designs and syllabus for both groups were designed and developed by the researchers, and regularly revised and validated through expert panels.

2.3.3. Treatment procedures

The experiment group signed in the Computer II-A, and the control group signed in the Computer II-B. All subjects were provided training on online course delivery during the first week and on effective search strategies during the second week of the implementation. Students were informed that the course would be Internet based which would let them participate in wherever they wished. All course activities ranging from course introduction to formative and summative evaluation were realized online. Face-to-face instruction was never resorted to in both the control and the experiment group.

Class activities were implemented beginning with the third week. Students were informed about the course objectives, syllabi, activities, evaluation criteria, learner support and related links on the main page. The experiment group was exposed to PBL activities involving ill-structured problem scenarios which were developed through the following steps (Jonassen, 1997):

1. Introduction of the problem situation: Ill-structured problems were introduced.
2. Expectations from the group members: Group members were introduced to each other followed by the introduction of expectations from each group member leading to an acceptable solution of the problem.
3. Opinions about the problem: Each group member delivered their ideas about the problem and reflected on their peers’ opinions through chat or discussion forum facilities.
4. Prior knowledge about the problem: Group members shared their prior knowledge on the problem.
5. Required information to solve the problem: Group members determined and discussed the type and extent of information necessary to solve the problem.
6. Determining plans: Each group member determined an individual study plan addressing the problem situation and reflected on their peers’ plans.
7. Solution process: Using their own and peers’ resources and discussing with group members and the instructor, each member created their own action plan leading to a potential solution for the problem.
8. Evaluation: Each group member reflected on their and their peers’ action plans. In addition, they assessed the contribution of each group member to the solution.

The control group, on the other hand, was provided with the summary contents each week. They were exposed to following activities (Horton, 2000):

- **Introduction of new information**: New content was delivered by the course instructor.
- **Information resources**: Electronic resources, class notes and presentations were provided.
- **Participation**: Students discussed on an instructor-led issue related to subject matter. In addition, students’ questions and comments regarding the subject were discussed.
- **Information sharing**: Students shared their resources in the online environment.
- **Evaluation**: Students’ responses to the instructor’s open-ended questions were evaluated. They were also asked to prepare a report or complete an assignment on the subject matter.
- **Feedback**: Students received constant and immediate feedback regarding their reports and assignments.

The experiment group (i.e. online PBL) was exposed to three problem situations in eight weeks. They completed the first two scenarios in three weeks and the last one in two weeks. After the problem situation was introduced, they tried to define the problem and shared their
prior knowledge with other group members. Sub-groups consisted of four students which were randomly assigned as well. Even though they were supposed to work in groups and implement PBL strategies during group activities, they were asked to prepare individual reports on the problem solution according to the standards determined at the beginning of the semester. The control group (i.e. online instructor-led) on the other hand, completed assignments according to predetermined standards, participated in instructor-led online discussion forums, and shared their comments with the instructor and other peers through online communication tools.

The same electronic resources were used for both the experiment and the control group. Both groups were allowed to share electronic resources they found. The experiment group was given all resources at the inception of the implementation without a guidance regarding the specific resource of a specific week so that they would improve their research and decision making skills. The control group was given the resources on a weekly basis according to the subject matter of the week. That is, the instructor was the decision maker regarding the subject matter and resources of a specific week.

In the PBL group, the instructor participated in discussion forums and encouraged participants to ask questions, respond to others’ inquiries, think deeper, conduct research, and make decisions. He asked instigating and challenging questions, and encouraged students to ask questions as well. However, he did not directly respond to student inquiries. In the online instructor-led group, the instructor directly responded to student inquiries and actively participated in online discussions as the leader. In brief, while the instructor was a guide and facilitator in the experiment group; he was the content maker, discussion leader, response provider and center of the online learning endeavors in the control group.

Online activities realized by both groups were evaluated on a weekly basis through a predetermined and clear-cut specification table. In addition, students in the online PBL group evaluated their peers for each problem situation through a peer assessment form. Averages of three peer evaluations constituted 20% of the participation grade. Both groups were provided feedback regarding their learning. The instructor regularly announced creative and interesting deeds of specific participants to increase motivation. The instructor was online and available everyday between 2 and 6 pm. through the messenger address cevrimiciegitim@hotmail.com in addition to the instant messaging system of the online platform.

2.4. Data analysis

Descriptive statistics were used to illustrate the demographics and the general picture of the subjects for each measurement. Two-way mixed design analyses of variance (ANOVA) were conducted to see the effects of online PBL and instructor-led practices on content knowledge and CTS scores. At the inception of interpreting significance of the results, the probability value was set as \( \alpha = .05 \).

3. Results

3.1. Content knowledge acquisition

In order to see whether the content knowledge test scores of the online PBL group increased more significantly than the scores of the online instructor-led group, prior content knowledge and content posttest scores of both groups were calculated first. Descriptive statistics are given in Table 1.

As shown in Table 1, the experiment group’s pretest mean (18.20) increased to 29.95 in the posttest whereas the control group’s pretest mean (18.30) increased to 27.40. That is, both groups had higher scores in the posttest. However, to see which group’s progress was better, two-way mixed design ANOVA was used which is summarized in Table 2.

As shown in Table 2, the progress levels of the experiment and the control group did not follow a different pattern through measurements \( F(1,38) = 3.423, p > .05 \). That is, online PBL did not have a different effect than online instructor-led activities in terms of content knowledge acquisition. Even though both groups had significantly higher scores in the posttest \( F(1,38) = 2173.612, p < .001 \), it was not possible to maintain that one of the group outperformed the other. However, the probability value was close to significance \( F(1,38) = 3.835, p = .058 \) on behalf of the PBL group, which should be revisited in further experiments.

Table 1
Descriptive statistics regarding pre- and post content knowledge.

<table>
<thead>
<tr>
<th>Group</th>
<th>Pretest</th>
<th></th>
<th>Posttest</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>X</td>
<td>SD</td>
<td>N</td>
</tr>
<tr>
<td>Online PBL (experiment)</td>
<td>20</td>
<td>18.20</td>
<td>2.87</td>
<td>20</td>
</tr>
<tr>
<td>Online instructor-led (control)</td>
<td>20</td>
<td>18.30</td>
<td>2.99</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 2
Summary of mixed design ANOVA conducted with content knowledge scores.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>327.387</td>
<td>39</td>
<td>30.012</td>
<td>3.835</td>
<td>.058</td>
</tr>
<tr>
<td>Group (PBL/instructor-led)</td>
<td>30.012</td>
<td>1</td>
<td>30.012</td>
<td>3.835</td>
<td>.058</td>
</tr>
<tr>
<td>Error</td>
<td>297.375</td>
<td>38</td>
<td>7.826</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within groups</td>
<td>2598.507</td>
<td>40</td>
<td>64.964</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measure (pre-posttest)</td>
<td>2173.612</td>
<td>1</td>
<td>2173.612</td>
<td>211.910</td>
<td>.000</td>
</tr>
<tr>
<td>Group * measure</td>
<td>35.12</td>
<td>1</td>
<td>35.12</td>
<td>3.423</td>
<td>.072</td>
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<tr>
<td>Error</td>
<td>389.775</td>
<td>38</td>
<td>10.257</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2925.894</td>
<td>79</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
3.2. Critical thinking skills

In order to see whether the CTS scores of the online PBL group increase more significantly than the scores of the online instructor-led group, CTS pre- and posttest scores were calculated as shown in Table 3.

As shown in Table 3, the experiment group's pretest mean (66.50) increased to 75.05 in the posttest whereas the control group's pretest mean (66.45) increased to 70.30. That is, both groups had higher scores in the posttest. However, to see which group's progress was better, two-way mixed design ANOVA was used which is summarized in Table 4.

As shown in Table 4, the progress levels of the experiment and the control group followed follow a different pattern through measurements ($F_{(1,38)} = 4.848, p < .05$). In this regard, it could be suggested that exposing students to online PBL and online instructor-led activities
had different effects on CTS scores. More specifically, the PBL group had higher gains in terms of CTS than the instructor-led group even though they were equal at the inception. This situation is illustrated in Fig. 1.

This situation was supported by several studies indicating that PBL improved high level skills including critical thinking.

4. Conclusions and discussion

The current study conducted in online PBL environment revealed that the PBL group and the instructor-led group did not differ in terms of knowledge-, comprehension- and application-level skills. Findings were somewhat in line with the Candela (1999) study showing that undergraduate students exposed to PBL environments did not outperform students in traditional settings. Similarly, Korucu (2007) compared the content knowledge acquisition scores of elementary school students assigned to PBL and collaborative learning groups, and claimed that the groups did not differ. However, the findings were not supportive of several studies in the literature maintaining the advantage of PBL over some other methods (Alper, 2003; Deveci, 2002; Elshafei, 1999). Such a difference could stem from the nature of the performance measures used. More specifically, some studies administered achievement tests addressing merely cognitive skills while others focused on psychomotor or sensory skills as well. In this regard, it can be suggested that PBL may not have a marginal effect on increasing knowledge-, comprehension- and application-level cognitive skills in comparison to other methods. Yan and Yalcin (2005) supported this claim through finding that PBL improved undergraduate learners’ higher order thinking skills with a particular emphasis on creative thinking skills. Thus, it may be plausible to administer measurement tools to address high level skills like analysis, synthesis and evaluation in addition to knowledge, comprehension and application. In addition, online interaction tools provided to the control group in the current study could be as effective as PBL activities in increasing low-level cognitive skills along with keeping motivation higher. This claim was supported by Wang (2005) indicating that synchronous discussion environments had a positive and significant effect on improving students’ cognitive skills.

Differences in the PBL research findings could also stem from the specific method used for the control groups. More specifically, the comparison of PBL with a student-centered method can lead to different findings than the comparison of PBL with a purely instructor-centered method. In the current study, the online instructor-led group made use of chat, forum, electronic resources, file sharing and other Internet tools provided. That is, they had the chance to interact with peers and with technology. In this regard, the method was not purely instructor-centered. Korucu (2007) also compared two student-centered methods (i.e. PBL vs. collaborative learning) which led to non-significant results. As both the current study and the Korucu (2007) study found no differences between the PBL and control groups, it can be suggested that if the control group was exposed to a more instructor-centered group, the differences can be greater. This suggestion was somewhat supported by the marginally significant difference between the experiment and the control group, which could have been greater if a purely instructor-centered method was implemented.

Age level of subjects can be another significant indicator of the differences in the PBL research. Elshafei (1999) and Alper (2003) conducted their study with secondary school students whereas Deveci (2002) worked with primary school students. Each study revealed that PBL was more effective than the control group in increasing achievement. However, the Candela (1999) study was conducted with undergraduate students similar to the current study which did not find a difference between the PBL and the control. Such findings implied that PBL could be more effective with younger learners.

Some researchers claimed that longitudinal studies were necessary to see the long-term effectiveness of PBL on learning outcomes. For instance, Blake, Hosokawa, and Riley (2000) compared the long-term effectiveness of PBL by comparing students exposed to traditional methods for two years with students exposed to PBL for three years. Findings revealed an advantage for the PBL group in terms of content knowledge scores. This suggested that implementing PBL for a short time may not be sufficient to see the effectiveness of the method on learning outcomes. The studies examined provided several explanations regarding this situation. For instance, the types and skill contents of the achievement tests, motivating aspects of online tools regardless of the method applied, and differentiating effects of PBL on different age groups. On the other hand, findings implying an advantage of PBL in terms of acquiring critical thinking skills were consistent with the studies examined. It was revealed that ill-structured problems used in PBL environments led learners to think deeper, question, discuss and conduct research. In addition, organization of the learning resources and the facilitating role of the instructor increased the difference between the PBL and the instructor-led group in terms of CTS scores. For instance, the Özdemir (2005) study indicated that students in a collaborative PBL environment outperformed those in an individual PBL environment in terms of critical thinking. Burris (2005) maintained that PBL improved critical thinking skills better than traditional classroom practices. Albanese and Mitchell (1993) conducted a meta-analysis covering 100 papers to investigate the PBL outcomes. Interestingly, it was indicated that learners in a PBL setting had lower scores than those in a traditional setting in terms of basic skills. On the other hand, it was revealed that learners in a PBL setting outperformed those in a traditional setting in terms of high level skills including problem solving and critical thinking. In addition, it was found that PBL learners’ mean showed a homogeneous distribution around the group mean whereas the distribution patterns in other settings were more heterogeneous. Similar to the Albanese and Mitchell (1993) study, Vernon and Blake (1993) conducted a meta-analysis and found that PBL was more effective in increasing critical thinking skills than traditional methods.

Even though both the online PBL and the online instructor-led group were exposed to the same platform along with same resources and online interactive tools; the groups differed in terms of using online tools and resources. The experiment group was exposed to ill-structured problem situations whereas the control group was exposed to predetermined and ready content units on a weekly basis. Such a difference could lead the PBL group to think deeper, conduct more research and discuss more effectively which could improve their high level thinking skills. The control group, on the other hand, did not need to question the content or conduct research which may have interfered with their critical thinking skills. These differences can explain the fact that the PBL group outperformed the instructor-led group in terms of CTS scores. Wang (2005) maintained that offering open-ended questions to students can improve students’ high level thinking skills. Chiang and Fung (2004) developed and implemented an online PBL system called MALESA, and found that the more learners resorted to critical thinking skills did judgments, the more they learnt.

The difference between the PBL and the instructor-led group may stem from the presentation of resources as well. Even though the resources were the same for both groups, the experiment group was given all resources at the inception of the implementation, and they were given a chance to question and decide whichever resource was applicable for a specific problem. That is, the resources were not re-
lated to a specific subject matter by the instructor; rather, students were allowed to relate the resources to subject matters. Such an approach may have led the PBL students to question more and conduct more research whenever they were not happy with the effectiveness of resources for a problem situation. The instructor-led group, on the other hand, was given the resources on a weekly basis each resource being related to the subject matter by the instructor. Such a structured and clear-cut implementation may have prevented them from implementing their high level thinking and researching skills. More specifically, the control group did not need to manage and transform information. As indicated in the literature (Oh & Jonassen, 2007), superficial information and individual performance had a negative and significant relationship. Using information superficially without selecting and transforming appropriate units and without evaluating its adequacy may have prevented from the control group to think deeper.

A final evaluation can be conducted about the CTS difference between the groups in regard to the roles of instructors. Even though the instructor provided guidance for both groups, he was a facilitator and moderator in the PBL group. Students’ perceptions regarding the implementation supported this assumption. More specifically, the experiment group mentioned the role of the instructor as a guide throughout the process. The instructor never provided them with direct responses; rather, he gave them clues leading to the problem solution. Similarly, Donnelly (2006) claimed that online PBL students perceived the instructor as a guide, assistant, facilitator and discussion participant. As a requirement of the PBL activities, the instructor provided learners with clues during online discussions and led them to think deeper, discuss more, reflect further and conduct more research. In contrast, students in the control group were provided with direct responses for their questions. Moreover, the corrections were always immediate. This led the control group students to use ready information without questioning and thinking deeper. In brief, the role assumed by the course instructor can have a significant influence on the development of critical thinking skills in an online PBL environment.

It can be suggested that both the PBL and instructor-led activities may be implemented to nourish knowledge-, comprehension- and application-type cognitive skills since the difference between the two groups was not significant in the current study. However, further comparisons between the methods implemented in the current study and other methods cited in the literature should be conducted to have in-depth knowledge about the individual efficiency of each method.

Even though both groups improved significantly in the CTS posttest, it was revealed that the online PBL group outperformed the online instructor-led group in terms of critical thinking. In this regard, online PBL practices can be implemented to improve learners’ high level skills such as critical thinking. Online PBL can be an effective alternative approach implemented in distance education practices. However, it should be taken into account that only specific parts of online courses should make use of the PBL. If the subject matter and content already allow instructors to implement collaborative practices, the use of PBL may be redundant. Implementation of PBL activities in accordance with the characteristics of the content and learners is expected to improve pre-service teachers’ technology using proficiencies and allow them to improve their high-order thinking skills through providing them with authentic and real-life problem situations.

Appendix A. Content Knowledge Test

1. Hilal examined the computer assisted instruction software to use in her class. She reached the following conclusions after the evaluation:

I. Student interaction is quite limited.
II. Visuals are not satisfactory and not organized well.
III. Students are not provided with sufficient clues and feedback.
IV. Some parts of the software do not respond on time.

Which two of the above conclusions stem from the same evaluation category?

a. III-IV
b. I-III
c. I-II
d. II-IV
e. II-III

2. Ahmet realized that successful students in his classroom are bored while he is implementing the new instructional software. He asked why they get bored and learnt that the software does not accept students’ alternative strategies and solutions. Which of the following explains this situation?

a. Special tutoring software explain new subject matters in an easy manner
b. Repetition and drill software sustain student motivation through short repetitions
c. Problem solving software lead learners to specific solution strategies
d. Scenarios of educational games are not consistent with the instructional objectives
e. Simulations are only used for strategy training

References


