A Five-Phase Learning Cycle Approach to Improving the Web-based Problem-Solving Performance of Students

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ABSTRACT

Internet technology has become an important channel for accessing information and solving problems. However, researchers have indicated that most students lack effective strategies for searching for information on the Internet, and hence their learning performance is not as good as could be expected. To address this issue, in this study, a five-phase learning cycle approach is proposed to conduct web-based problem-solving activities. From the experimental results, it was found that the students’ web-based problem-solving performance was improved after participating in the learning activities. Moreover, based on the analysis of 170 elementary school students’ web information-searching portfolios as well as their feedback to the assessments, questionnaires and interviews, it was found that the students’ problem-solving ability and their web-based problem-solving performance were highly correlated, implying that the five-phase learning cycle approach could be able to improve not only the students’ web-based problem-solving performance, but also their general problem-solving ability.

Keywords

Web-based information-searching, Problem-solving ability, E-portfolios, Interactive learning environments

Introduction

High-order thinking abilities are viewed as an important competence in education nowadays. Among these abilities, problem solving ability has long been an objective of education. In the past decades, diverse definitions or conceptions of problem solving have been proposed by researchers and educators. A well-recognized definition is the process of solving problems via understanding them, then devising, carrying out and evaluating plans to solve them (Gagne, 1985; Polya, 1981). For example, Sternberg (1988) indicated that problem-solving ability should encompass six skills: (1) identifying the nature of the problem; (2) choosing problem-solving steps; (3) choosing problem-solving strategies; (4) choosing appropriate information; (5) allocating proper resources; and (6) monitoring the problem-solving process. ITEA (2000) defined problem solving as the process of clarifying a problem, making a plan, implementing the plan, and evaluating the result in order to solve the problem to meet a human need or want. Some researchers have emphasized that “creativity” is one of the critical keys to solving problems (Hwang et al., 2007; Higgins, 1994). Some have further indicated that problem solving is a complex thinking procedure which should include the processes of critical thinking, creative thinking and reasoning, as shown in Figure 1 (Higgins, 1994; Hwang, Chen, Dung, & Yang, 2007).

Figure 1. Three high-order thinking abilities involved in problem-solving ability
Previous studies have revealed several factors that might affect students’ problem-solving abilities, such as intelligence quality, learning materials, learning methods, problem-solving instruction strategies, and parents’ socioeconomic background (Oloruntegbe, Ikpe, & Kukuru, 2010). Among these factors, learning methods and problem-solving instruction strategies are both considered as key factors that influence students’ problem-solving abilities; consequently, many studies related to these issues have been conducted in recent years (Hwang & Kuo, 2011; Kuo, Hwang, & Lee, 2012; Tsai & Shen, 2009). In addition, researchers have reported correlations among information-searching skills, cognitive structure and problem-solving abilities (Eisenberg & Berkowitz, 1990). Bilal (2002) has further indicated that the lack of effective information-searching strategies and high-order thinking abilities could influence students’ performance in searching for information on the Internet. However, most previous research concerning students’ information-searching and problem-solving abilities has mainly focused on the difficulties students encounter in their web searching, while failing to provide prescription strategies for the improvement of information-searching and problem-solving abilities, including selecting, abstracting and organizing the searched data (Lee, 2012; Laxman, 2010; Walraven, Brand-Gruwel, & Boshuiaen, 2009). Therefore, an important educational issue emerges regarding how to guide individuals to construct their own knowledge via the process of collecting data, and analyzing and integrating information on the Internet autonomously. Hwang and Kuo (2011) further called such learning activities that engage students in comprehending a series of questions related to a specific issue, and seeking, selecting, abstracting, and summarizing information on the Web to answer the questions, "web-based problem solving." They indicated that with proper design of the target issue and the related questions, the students could be benefited by linking the knowledge learned from textbooks to real-world contexts.

Consequently, this study proposes a five-phase learning cycle approach to help students foster the abilities required to deal with web-based problem-solving activities. To test the influence of the proposed learning approach, a single-group pretest-posttest design was employed in the study. Such a single-group research design has been employed by many previous studies in investigating the effects of learning approaches and strategies (Liao, 2007; Sak & Oz, 2010; Sipe & Curlette, 1996; Yang, 2007). In addition, we attempt to investigate the critical factors that might affect students' web-based problem-solving performance via the proposed five-phase learning cycle approach based on individuals' e-portfolios recorded during a series of learning activities. Accordingly, a hybrid analysis combining quantitative and qualitative data, including students’ information-searching portfolios, is applied to reciprocally investigate the factors influencing the students’ web-based problem-solving performance.

Literature review

Web-based problem-solving

Recently, many educational institutes have begun to encourage educators to conduct diverse web-based learning activities in which students are given more opportunities through knowledge construction to improve their web-based problem-solving performance (Lefrancois, 1997). Accordingly, learning methods and problem-solving instruction strategies are both considered as key factors that influence students’ problem-solving abilities (Hwang, Wu, & Chen, 2012); consequently, many studies related to these issues have been conducted in recent years (Hwang & Kuo, 2011; Kuo, Hwang, & Lee, 2012; Tsai & Shen, 2009).

Researchers have found that student problem-solving ability can be facilitated through the integration of problem-solving strategies and computer technologies (Merrill & Gilbert, 2008; Ferreira & Lacerda Santos, 2009; Chiou et al., 2009). For instance, Lo (2009) proposed a computer-mediated communication (CMC) tool to build online communication environments for problem-based learning (PBL) based on the problem solving theory. The empirical evidence showed that students were able to communicate, discuss, and co-build the knowledge from the collected information. With the online communication, they were able to seek solutions to the problems raised in learning activities. Meanwhile, the students were satisfied with the online PBL course. Ferreira and Lacerda Santos investigated the combination of collaborative learning theory and problem solving theory into web-based learning scenarios. Their research results showed that students could improve their problem-solving competences through well-structured collaborative problem-solving activities guided by the teacher. In addition, Yu, She and Lee (2010) investigated the effects of two factors: the mode of problem-solving instruction (i.e., Web-based versus non-Web-based) and the level of academic achievement (i.e., high achievers versus low achievers) on students’ problem-solving ability and biology achievement. Their research findings showed that web-based problem-solving instruction has the potential to enhance and sustain the learners’ problem-solving skills over an extended period of time.
Several studies have further shown that effective strategies can not only effectively improve students' web-based problem-solving performance, but can also increase their positive attitudes toward problem solving (Brand-Gruwel, Wopereis, & Walraven, 2009; Hwang & Kuo, 2011). To develop effective strategies, it is necessary to find the critical factors that affect students' web-based problem-solving performance. Consequently, it has become an important and challenging issue to investigate the factors related to web-based problem-solving (Huang, Liu, & Chang, 2012; Kuo, Hwang, & Lee, 2012).

**E-portfolios**

Portfolios refer to a representative collection of a student’s work, which often amounts to documentation as a personal learning record (Evans, Daniel, Mikovich, Metze, & Norman, 2006). Learning portfolios are usually developed to fulfill the needs of assessing the quality of the student’s past or ongoing performance. Learning portfolios provide educators with direct evidence of the quality of students’ work and the information for evaluating their work in progress (Zubizarreta, 2004).

Researchers believe that e-portfolios are one of the most effective approaches to understanding the value of an educational model of assessment that can be used to guide independent learning, self-evaluation and reflective practice (Alexander & Golja, 2007). These processes also provide a clear set of criteria for evaluating actual learning outcomes (Garrett, 2011; Herner-Patnode & Lee, 2009). Previous studies have proved that e-portfolios are able to facilitate teachers’ analysis and assessment of students’ learning performance. For example, Hwang, Tsai, Tsai and Tseng (2008) proposed a web-based searching behavior analyzing system called Meta-Analyzer which is able to help teachers analyze students' learning behavior when using search engines for problem solving by recording the students’ web-based problem-solving portfolios, including the keywords they use to search for information on the web, the web pages they browse, the time they spend on selecting and browsing the web pages, the web pages they adopt to answer the questions, and their answers to individual questions. Teachers or researchers are able to access those e-portfolios via a teacher interface provided by Meta-Analyzer. Chang (2008) developed a web-based portfolio assessment system for assessing students' self-perceived learning performance. His research findings show that the system is more effective for the overall self-perceived learning performance of poorly motivated students than it is for highly motivated students. Akcil and Arap (2009) found that education faculty students had positive opinions about the usage of e-portfolios for educational purposes which increased their motivation to study. Kabilan and Khan (2012) further indicated that e-portfolios as a monitoring tool could help pre-service English language teachers recognize their learning and identify their strengths and weaknesses.

To sum up, e-portfolios provide educators with insights into students’ learning behaviors, and enable them to further assess the students’ learning performance. In addition, they can be used to compensate for the weaknesses of quantitative analysis approaches by contextualizing learners’ behaviors in the web-based learning environment. Consequently, with the support of e-portfolio analysis, the factors affecting students’ learning achievement shall be inferred more accurately in this study.

**Design and implementation of the research**

**Research questions**

According to the purpose of the study described in the introductory section, the research questions addressed are listed below:

1. Could students’ web-based problem-solving performance be significantly correlated to their problem-solving ability via the proposed learning approach?
2. What sub-abilities relating to web-based problem-solving ability can be found via the students' e-portfolios?
3. What critical factors affecting the students’ web-based problem-solving performance can be deduced by a hybrid analysis of quantitative and qualitative data including the students’ information-searching portfolios?
Research method and participants

The research study using a single-group pretest–posttest design was carried out on the influence of the five-phase learning approach on web-based problem solving ability. In addition, the students' web-based problem-solving portfolios were analyzed to investigate critical factors via the Dependent samples t test method. Such a single-group research method has been adopted by several previous studies (Liao, 2007; Sak & Oz, 2010; Sipe & Curlette, 1996; Yang, 2007). For instance, Yang (2007) adopted a one-group pretest-posttest design to investigate the effect of doing history projects on promoting high school students' critical thinking skills; Sak and Oz (2010) also conducted a series of creative thinking activities with a one-group pretest-posttest design.

A total of 170 elementary school 5th graders ranging from 11-12 years old from three elementary schools in southern Taiwan participated in this study. The samples were chosen owing to taking an identical social studies course with very similar progress, and all having had one year of web information searching experience. In addition, the study examined the normal distribution in the pretest of the web-based problem-solving performance and problem-solving ability of the participants, showing that the skewness and kurtosis of their web-based problem-solving performance were .04 and .01 respectively, while those of their problem-solving ability were -.07 and -.97. Furthermore, in the posttest, the skewness and kurtosis of web-based problem-solving performance were - .93 and .34, and those of problem-solving ability were .23 and .19. Thus, the examined results fit the criteria of the normal distribution stated by Kline (1998) of skewness below 3.0 and kurtosis below 10.

A five-phase learning cycle approach

The experiment design was constructed on the basis of the problem-solving theory and constructivism, as shown in Figure 4. A five-phase learning cycle, adapted from Eisenberg and Berkowitz’s Big Six method (Eisenberg & Berkowitz, 1996), was used to scaffold students in the process of adopting keywords, identifying information and abstracting information for a given social issue via Meta-Analyzer.

The experiment was conducted over a seven-week period, including four stages, namely a pre-test, learning system orientation, five weeks of learning activities, and a post-test. Moreover, a total of six sets of constructive questions concerning different social issues, namely ‘credit card slaves,’ ‘renewable energy,’ ‘the greenhouse effect,’ ‘the garbage problem,’ ‘water shortages,’ and ‘the falling birthrate problem,’ were designed and embedded in Meta-Analyzer to provide the students with web-based problem-solving practice, as shown in Appendix 1. Among these issues, the first, ‘credit card slaves,’ was used as both the pre- and post-test issue for evaluating their web-based problem-solving performance before and after the learning activity, while the other issues were used as training cases in the learning activities.

Prior to the experiment, all of the students were given a demonstration and practice using the Meta-Analyzer system, as well as instruction in how experts solve problems using problem-solving skills. Afterwards, to enhance the students’ web-based problem-solving perceptions and competence, a five-phase learning cycle based on a given social issue was conducted for eighty minutes each week in the web-based problem-solving context. The five phases of the learning cycle are described in detail as follows:

1. Prior knowledge construction
   Before conducting the web-based problem-solving activities, fundamental knowledge concerning the given social issue is instructed in the introductory session.

2. Keyword adoption
   In this phase, the teacher mainly elaborates what keywords or synonyms could be employed based on the given social issue.

3. Information identification
   The third phase of the learning cycle is to guide students to identify relevant web pages, to look for accurate solutions, as well as to criticize and recognize the advantages and disadvantages of solutions before solving the problem.
4. Information abstraction
   In this phase, students are taught to judge what pages need to be conserved and how to abstract useful information to solve the problem via retrieving information from the web pages.

5. Thinking elaboration
   The last phase of the learning cycle is to require them to express their ideas based on the given issue freely on their own. This phase also offers an opportunity for peers to reflect on what they have done, which is consistent with both Piaget’s theory of cognitive development (Piaget, 1970) and with the theory of social constructivism (Vygotsky, 1978).

![Figure 4. Experiment design in the study](image)

The five-phase learning cycle lasted for 5 weeks during which the students practiced with 5 social issues, one per week. The social studies teacher only provided instruction and scaffolding for the first two issues. The scaffolding was faded out and removed in the last three issues so that the students could learn to solve the problems on their own. After the learning activities for all of the social issues were completed, the post-test of web-based problem-solving performance and post-questionnaires were conducted within a period of sixty minutes. Interviews with students were arranged on the basis of the analysis results of the collected quantitative data for further investigation of the factors affecting their web-based problem-solving performance in the proposed learning environment.

Web-based learning environment

To collect more practical data from students’ learning portfolios, the web-based searching behavior analyzing system, Meta-Analyzer (Hwang et al., 2008), was used to assist in tracing and analyzing the learners’ information-searching behaviors for a series of questions related to some specific issues. It has been used for analyzing the online information-searching behaviors of learners by previous studies (Chiou, Hwang, & Tseng, 2009; Hwang, Chen, Tsai, & Tsai, 2011). For example, Chou (2008) employed Meta-Analyzer to record students’ information-searching behaviors for investigating the relationships among their informal reasoning, decision-making and online information commitments on socio-scientific issues; Tu, Shih and Tsai (2008) employed Meta-Analyzer to analyze eighth graders’ web searching strategies and outcomes. Recently, Tsai, Hsu and Tsai (2012) used Meta-Analyzer to
investigate the effects of different information searching strategies on high school students’ science information searching performance.

The student interface of Meta-Analyzer consists of three operation areas: The question and answer area is located on the left-hand side of the browser, the information-searching area is located on the upper-right side, and the web pages found by the search engine are given on the lower-right side. To answer the questions, the students can input keywords to search for information and then browse the searched web pages that might be relevant to the topic, as shown in Figure 2.

![Figure 2. Student interface of Meta-Analyzer](image)

**Research instruments**

The assessment of problem-solving ability refers to the test items proposed by Zhan and Wu (2007). The assessment consists of 10 items for evaluating the students’ ability in terms of “awareness of problems,” “identification of the nature of problems,” “recognition of factors related to the problems,” “identification of more information needed to solve the problems” and “determination of solutions.” The perfect score of the assessment is 20. To ensure inter-rater reliability, three senior social studies teachers from three elementary schools were involved in the rating. Moreover, before the formal rating of the experiment, 32 non-experimental high-grade students participated in the test in an attempt to verify the correlation among the raters. Measured via Pearson correlation analysis, the inter-rater reliability of the pre-test has a Cronbach's $\alpha$ value of 0.915, showing high consistency between the ratings of the various teachers.

The assessment of web-based problem-solving performance refers to one of the question sets proposed by Kuo, Hwang and Lee (2012). It contained four sub-questions embedded in the Meta-Analyzer system and was used to evaluate the students’ web-based problem-solving performance before and after the learning activity. The maximum score of each sub-question is 10, and the perfect score of the assessment is 40. To ensure inter-rater reliability, three senior social studies teachers from three elementary schools were invited to perform the rating. Moreover, before the formal rating of the experiment, a non-experimental high-grade class participated in the test in an attempt to verify the correlation among the raters. The inter-rater reliability was measured with a Cronbach's $\alpha$ value of 0.89 via Pearson correlation analysis, showing high consistency between the ratings of the various teachers.
The questionnaire survey is structured as follows: The first part consists of students’ personal and academic data, while the second part consists of three dimensions for assessing the students’ responses regarding the proposed learning approach. The questionnaire consists of three dimensions with sixteen items in total, including 5 items for task-technology fit developed by Goodhue and Thompson (1995), 5 items for use intention developed by Davis (1989), and 6 items for web-based problem-solving performance originating from the measure proposed by Gagne et al. (1985). These three dimensions are measured with a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). For validation of the questionnaire survey, factor analysis was conducted with 30 students who were non-experimental samples prior to the experiment. Principal component analysis was used as the extraction method to extract 22.76%, 20.73% and 15.69% of variance in rotation sums of squared loadings in terms of dimensions of task-technology fit, use intention and web-based problem-solving performance respectively, and the total variance explained reaches 59.18%. After the experiment, the data of a total of 170 fifth graders were analyzed with factor analysis to measure the sampling adequacy, in which KMO provides an index of proportion of variance among variables. The results of the analysis showed that the KMO reached 0.92, indicating that the questionnaire items exhibit common variance. Accordingly, internal consistency reliability was performed individually for the three different dimensions. The Cronbach’s \( \alpha \) for these dimension presented at least 0.82, meaning that the measuring tools of the study have high reliability. Moreover, these items were modified and adapted through an iterative personal interview process with two senior social studies teachers and one professor to verify the completeness, wording, and appropriateness of the instrument and to confirm the content validity. The Cronbach's \( \alpha \) values of the three dimensions are 0.82, 0.87 and 0.88, respectively.

In order to measure the students’ e-portfolios compiled during the learning process, thirteen indicators were embedded in Meta-Analyzer to record the students’ online searching portfolios that were employed in the study. These indicators have been widely used in many web-based learning activities for analyzing students' online learning achievement, and allow teachers to evaluate the students’ learning status and adapt instructional strategies accordingly (Chou, 2008; Hwang & Kuo, 2011; Kuo, Hwang, & Lee, 2012; Kuo, Hwang, Chen, & Chen, 2012). These quantitative indicators can be divided into three dimensions, namely keyword-adopting ability, information-selecting ability and question-answering ability (Hwang et al., 2008).

Figure 3 shows an illustrative example of a student’s searching portfolio recorded by Meta-Analyzer, including the student’s identification, the student’s answers to each question, the teacher’s evaluation of each question, the time duration for each operation, and so on. Via browsing the portfolios, researchers or teachers can analyze the detailed searching behaviors of the students.

Figure 3. One student’s online information-searching behaviors recorded in the database
Results

Correlation analysis of problem-solving outcomes

This study firstly investigated the correlation between the students’ web-based problem-solving performance and their problem-solving ability via employing the Pearson correlation analysis method. Table 1 shows the analysis result of the pre-tests of both learning outcomes. A medium correlation between two dependent variables \((r = 0.317, p < .01)\) was found. Moreover, by analyzing the post-tests of both learning outcomes, a close to large correlation \((r = 0.497, p < .01)\) was derived, as shown in Table 2. This result could imply that the more the students’ web-based problem-solving performance is promoted, the better their problem-solving ability is.

In this study, the students’ web-based problem-solving performance was improved after a series of training cases, which could be the reason why their problem-solving ability was improved as well. Thus, it is concluded that engaging students in web-based problem-solving activities could foster both their problem-solving ability and web-based problem-solving performance, which is consistent with previous studies (Argelagos & Pifarre, 2012; Hwang & Kuo, 2011; She et al., 2012).

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Web-based problem-solving performance</th>
<th>Problem-solving ability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web-based problem-solving performance</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Problem-solving ability</td>
<td>.317**</td>
<td>1</td>
</tr>
<tr>
<td>Note. **p &lt; .01</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Web-based problem-solving performance</th>
<th>Problem-solving Ability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web-based problem-solving performance</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Problem-solving Ability</td>
<td>.497**</td>
<td>1</td>
</tr>
<tr>
<td>Note. **p &lt; .01</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis of web-based problem-solving portfolios

The students searching portfolios were further analyzed for investigating their web-based problem-solving performance. Paired-sample \(t\) tests were employed to analyze the pre- and post-test records in terms of the thirteen indicators provided by Meta-Analyzer, as shown in Table 3.

<table>
<thead>
<tr>
<th>Ability</th>
<th>Meta-Analyzer Indices</th>
<th>Test</th>
<th>Mean</th>
<th>S.D.</th>
<th>(t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keyword adoption</td>
<td>Average number of keywords used in a search operation</td>
<td>Pre-test</td>
<td>14.31</td>
<td>7.41</td>
<td>12.40***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post-test</td>
<td>8.58</td>
<td>4.41</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of search attempts for answering the question</td>
<td>Pre-test</td>
<td>3.62</td>
<td>3.71</td>
<td>3.40**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post-test</td>
<td>3.03</td>
<td>2.60</td>
<td></td>
</tr>
<tr>
<td>Information Selection</td>
<td>Total time for web page selection ('Sec.)</td>
<td>Pre-test</td>
<td>80.67</td>
<td>106.65</td>
<td>2.61**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post-test</td>
<td>64.52</td>
<td>93.08</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of different browsed and non-adopted pages</td>
<td>Pre-test</td>
<td>3.75</td>
<td>4.31</td>
<td>-3.38**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post-test</td>
<td>4.73</td>
<td>5.43</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total time for browsing the different non-adopted pages ('Sec.)</td>
<td>Pre-test</td>
<td>124.30</td>
<td>173.51</td>
<td>-2.96**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post-test</td>
<td>154.78</td>
<td>191.39</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of browsed non-adopted pages with revisits taken into account (time)</td>
<td>Pre-test</td>
<td>1.32</td>
<td>2.45</td>
<td>-3.72***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post-test</td>
<td>1.91</td>
<td>3.01</td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Answer</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total time for browsing non-adopted pages with revisits taken into account (Sec.)</strong></td>
<td>Pre-test</td>
<td>32.65</td>
<td>91.53</td>
<td>-2.43*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post-test</td>
<td>45.60</td>
<td>85.26</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Number of marked but not adopted pages</strong></td>
<td>Pre-test</td>
<td>0.12</td>
<td>0.17</td>
<td>-2.16*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post-test</td>
<td>0.21</td>
<td>0.31</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Number of different adopted pages</strong></td>
<td>Pre-test</td>
<td>1.02</td>
<td>0.81</td>
<td>-4.45***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post-test</td>
<td>1.31</td>
<td>1.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total time for browsing the different adopted pages (Sec.)</strong></td>
<td>Pre-test</td>
<td>59.16</td>
<td>104.39</td>
<td>-2.05*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post-test</td>
<td>69.05</td>
<td>92.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Number of adopted pages with revisits taken into account</strong></td>
<td>Pre-test</td>
<td>.75</td>
<td>1.34</td>
<td>-0.56</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post-test</td>
<td>.85</td>
<td>1.29</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total time for browsing the adopted pages with revisits taken into account (Sec.)</strong></td>
<td>Pre-test</td>
<td>45.11</td>
<td>118.98</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post-test</td>
<td>46.06</td>
<td>114.16</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Number of marked and adopted pages</strong></td>
<td>Pre-test</td>
<td>.36</td>
<td>0.61</td>
<td>-2.17*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post-test</td>
<td>.44</td>
<td>0.66</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note:* N = 170. *p < .05, **p < .01, ***p < .001, #Sec. = seconds

In terms of keyword-adopting ability, the post-test for the indicators of “average number of keywords used in a search operation” \(t = 12.40, p < .001\), and “number of search attempts for answering the question” \(t = 3.40, p < .01\) had significant improvement over the pre-test.

In terms of information selecting ability, the post-test for the indicators of “total time for web page selection” \(t = 2.61, p < .01\), “number of different browsed and non-adopted pages” \(t = -3.38, p < .01\), “total time spent browsing the different non-adopted pages” \(t = -2.96, p < .01\), “number of browsed non-adopted pages with revisits taken into account” \(t = -3.72, p < .001\), “total time spent browsing non-adopted pages with revisits taken into account” \(t = -2.43, p < .05\) and “number of marked but not adopted pages” \(t = -2.16, p < .05\) were significantly better than in the pre-test. Moreover, in Figure 5, the indicator “total time for web page selection” shows an apparent decreasing tendency in the learning activities, implying that the students were gradually able to shorten the web page selecting time due to adopting more appropriate keywords for the questions. In addition, both indicators “total time for browsing the different non-adopted pages” and “total time for browsing the different non-adopted pages with revisits” exhibit an apparent increasing tendency during the learning activities. These quantitative results show that the students were willing to spend more time browsing different web pages for the correct answers to the questions, implying that their information selecting ability has been significantly promoted.

![Figure 5. Students’ information selecting portfolios for a series of web-based problem-solving activities](image)

In terms of question-answering ability, the post-test for the indicators “number of marked and adopted pages” \(t = -2.17, p < .05\), “number of different adopted pages” \(t = -4.45, p < .001\) and “total time for browsing the different
adopted pages” ($t = -2.05, p < .05$) had significant improvement over the pre-test. These quantitative results show that the students would spend more time referring to different adopted pages to identify answers to the questions, implying that their question-answering ability was significantly promoted.

On the whole, the information-searching portfolios reveal that the participants’ keyword-adopting ability, information-selecting ability and question-answering ability all made noticeable progress according to the pre- and post-test quantitative results, implying that their web-based problem-solving performance significantly improved via a series of learning activities related to social issues embedded in the proposed learning approach.

**Analysis of questionnaires and interview results**

The questionnaire explored task-technology fit, which considers both the task for which the technology is used and the fit between the task and the technology. The questionnaire was evaluated by employing Confirmatory Factor Analysis (CFA) based on three criteria suggested by Fornell and Larcker (1981), namely: (1) All indicator factor loadings should be significant and exceed 0.5; (2) Composite reliabilities (CR) should exceed 0.7; and (3) Average variance extracted (AVE) by each construct should exceed the variance due to measurement error for the construct (i.e., AVE should exceed 0.5). Accordingly, all the standard factor loading values in the confirmatory factor analysis of the measurement model exceed 0.5 and are significant at $p = 0.001$. In addition, the CR of the constructs range from 0.84 to 0.88, and the AVE ranges from 0.52 to 0.56. Therefore, all three conditions for convergent validity are met, which indicates good internal consistency (Fornell & Larcker, 1981).

The average scores of the questionnaire items ranged from 3.86 to 4.23, as shown in Table 4, implying that most of the students agreed that the web-based problem-solving approach could guide them to solve problems. The questionnaire also explored use intention, which refers to an individual’s subjective likelihood of performing a specified behavior (Ajzen, 1985). The average statistical results of the questionnaire for this aspect ranged from 4.07 to 4.19, indicating that most of the students wished to learn other subjects via this kind of learning mode in the future.

<table>
<thead>
<tr>
<th>Questionnaire</th>
<th>Items</th>
<th>S.D</th>
<th>Mean</th>
<th>FL</th>
<th>CR</th>
<th>AVE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Task-Technology Fit</strong> (adapted from Goodhue and Thompson (1995))</td>
<td>1. I have been provided with the needed functions for completing the learning tasks.</td>
<td>.07</td>
<td>3.95</td>
<td>0.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. The learning approach can guide me to search for relevant information efficiently based on the social issues.</td>
<td>.37</td>
<td>3.86</td>
<td>0.77</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. The learning approach can guide me to understand the needed information for the social issues.</td>
<td>.53</td>
<td>4.04</td>
<td>0.77</td>
<td></td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>4. The learning approach can guide me to deeply understand the meaning of social issues.</td>
<td>.54</td>
<td>4.15</td>
<td>0.72</td>
<td></td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td>5. The learning approach can guide me to figure out how to think about and solve social problems.</td>
<td>.56</td>
<td>4.23</td>
<td>0.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Use intention</strong> (adapted from Davis (1989))</td>
<td>1. I will keep adopting this kind of learning mode in my social studies classes.</td>
<td>.59</td>
<td>4.07</td>
<td>0.70</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. I will adopt this kind of learning mode to enhance my independent thinking ability.</td>
<td>.54</td>
<td>4.10</td>
<td>0.77</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. I would like to adopt this kind of learning mode in the future.</td>
<td>.52</td>
<td>4.12</td>
<td>0.77</td>
<td>0.87</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>4. I would like to recommend this kind of learning mode to my peers.</td>
<td>.53</td>
<td>4.16</td>
<td>0.77</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Overall, I wish to learn other subjects via this kind of learning mode in the future.</td>
<td>.52</td>
<td>4.19</td>
<td>0.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Web-based problem-solving performance</strong></td>
<td>1. I believe this kind of learning mode could enhance both my keyword-adopting and information identifying abilities.</td>
<td>.55</td>
<td>4.25</td>
<td>0.81</td>
<td>0.88</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>2. I believe this kind of learning mode could promote</td>
<td>.54</td>
<td>4.31</td>
<td>0.75</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Web-based problem-solving performance refers to an individual’s subjective likelihood of performing a series of web-based problem-solving activities. The average statistical results of the questionnaire for these items ranged from 4.21 to 4.31, showing that a large number of the students positively agreed with and believed that the proposed learning approach applied to the social studies course could not only enhance their understanding of social issues, but could also promote both their problem-solving ability and their information-searching ability on the web.

To derive more insights into the participants’ responses regarding their web-based problem-solving performance, thirty-six students with different levels of achievement were randomly chosen to take part in semi-structured interviews. The interview transcripts were analyzed based on the grounded theory of quantitative analysis (Glaser & Strauss, 1967) in order to infer the critical factors affecting the learners’ web-based problem-solving performance. The grounded theory, a qualitative research approach proposed by Glaser and Strauss (1967), was employed to analyze the interviewed results in the study. It consists of several key analytic strategies: (1) Coding: the process for categorizing qualitative data and describing the implications and details of these categories (e.g., the students’ responses related to the positive effects of the learning approach on their keyword-adopting ability); (2) Memoing: the process of recording the thoughts and ideas of the researcher as they evolve throughout the study (e.g., the researchers took memos by writing down the key words or key points immediately when the students addressed something related to the impacts of the five phase strategies); and (3) Summarizing and generalizing: the process of pulling all of the details together to help make sense of the data by summarizing the findings and determining the most critical factor or point (e.g., by summarizing all of the key points from the students, the researchers were able to find the most important factors affecting the students’ web-based learning performance).

To investigate the students' perceptions of what potential factors would affect their web-based problem-solving performance, the following interview questions were used to elicit their opinions:

1. Do you think the proposed learning cycle approach can benefit you in improving your web-based problem solving? Why?
2. What abilities do you think are being improved in such a learning context? Why?
3. Do you think it is applicable to collocate a series of social issues in the Meta-Analyzer learning system? Why?
4. Would you like to apply such a proposed learning approach in other subjects in the future? Why?

From the interview, it was found that most of the students owed their web-based problem-solving performance to two major factors, that is, "Keyword-adopting and web information-searching abilities" and "Task-technology collocation."

Among the thirty-six students, twenty (55%) indicated that “keyword-adopting and web information-searching abilities” was the most important factor affecting their web-based learning performance. For example, one student indicated that "After participating in the learning activity, I understand the importance of identifying the key points of a problem before solving it. I need to carefully determine the keywords first in order to find useful information on the web." This finding is consistent with previous research indicating that better web learning performance and outcomes could be achieved by improving students’ keyword or synonym identifying and information retrieval abilities (Kane & Trochim, 2004; Tsai, Tsai, & Hwang, 2011; Saunders, 2008).

In terms of Task-technology collocation, eleven of the students (32%) thought that technology-enhanced learning cannot successfully achieve the teaching goal without effective learning strategies and learning tasks, implying the importance of embedding learning strategies and tasks into technology-enhanced learning environments, which echoes the findings of previous studies (Alexiou & Paraskeva, 2010; Casanova, Moreira, & Costa, 2011; Dreyer &

<table>
<thead>
<tr>
<th></th>
<th>my information selecting and abstracting abilities.</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>I believe this kind of learning mode could facilitate me to solve problems on the Internet.</td>
<td>.648</td>
<td>4.29</td>
</tr>
<tr>
<td>4.</td>
<td>I believe this kind of learning mode could extend my perceptions in analyzing any problem.</td>
<td>.543</td>
<td>4.21</td>
</tr>
<tr>
<td>5.</td>
<td>I believe this kind of learning mode could help me learn more about social issues.</td>
<td>.564</td>
<td>4.29</td>
</tr>
<tr>
<td>6.</td>
<td>I believe this kind of learning mode could enhance my understanding of social issues.</td>
<td>.569</td>
<td>4.28</td>
</tr>
</tbody>
</table>

Note. N = 170. a FL: factor loading; b CR: composite reliability; c AVE: average variance extracted
Nel, 2003). For example, one student indicated that "Using this system (i.e., Meta-Analyzer) to realize and solve a series of learning tasks is a good way to enhance my online problem-solving competence." Another student stated that "Social studies issues are well-designed in Meta-Analyzer, which effectively guides me to solve problems in a step-by-step and easy-to-follow manner."

**Discussion and conclusions**

In this study, a web-based problem-solving approach was proposed and used to investigate students’ learning performance via a hybrid analysis of quantitative and qualitative methods, in which the students’ web information-searching portfolios were analyzed to assess their performance. The statistical results show that the students’ web-based problem-solving performance as well as their problem-solving ability was improved via the proposed learning approach. This improvement could be attributed to the proposed approach based on problem-solving theory whereby the students were required to solve social issues following the five-phase learning cycle via the Internet resource. This also implies that the students’ learning performance is affected by interaction with cognitive and social environmental factors, which confirms that technology alone does not cause learning to occur (Bitter & Pierson, 1999). That is, the participants expressed their positive responses regarding the dimension of task-technology fit, showing that a series of social issues embedded in Meta-Analyzer could effectively guide them to figure out how to think deeply about and solve social problems. Moreover, they also gave positive responses regarding the dimension of use intention, indicating that the benefit of the proposed learning environment could strengthen their intentions so that it may be conducted in other subjects. Thus, this corresponds to the perspective of social cognitive theory, in which human behaviors have reciprocal interaction with cognitive, behavioral and environmental influences (Bandura, 1986). In other words, if individual students could obtain support from peers or teachers when conducting a complex learning task, they may gain better learning effectiveness.

Furthermore, the students’ information-searching portfolios revealed that their keyword-adopting, information-selecting and question-answering abilities were significantly enhanced via the series of web-based problem-solving activities. This result is consistent with previous studies (Coles & Robinson, 1989; Higgins, 1994; Kuo, Hwang, & Lee, 2012) which found that keyword-adopting and information-selecting abilities are critical to one's information searching ability on the web. Thus, according to the quantitative and qualitative analyses including the students’ information-searching portfolios, we could deduce that the process of web-based problem-solving performance should consist of critical thinking, creative thinking, reasoning thinking and information-searching abilities, based on the previous studies and current research findings, as shown in Figure 8. That is, students’ information-searching (IS) ability could be the critical factor affecting their web-based problem-solving (WPS) performance. This inferred result of the study could provide a framework for practitioners or educators in the educational field who are engaged in designing web-based problem-solving learning activities.

![Figure 8. The high-order thinking process of web-based problem-solving performance](image)

Although this study provides insights into what critical factors determine students’ web-based problem-solving performance in the proposed web-based learning approach, further investigations might be needed to confirm and extend the inferred results of the study. Thus, several issues need to be considered for future research. First, the extended studies can involve different groups of subjects who experience different learning approaches under more...
controlled conditions in order to make more significant conclusions. Second, further study may be needed to add more latent variables relating to web-based problem-solving performance via structural equation modeling (SEM). A hybrid analysis of SEM and e-portfolios is more likely to accurately explain what determinant factors could influence students’ web-based problem-solving performance. Third, further examination of the effects of individual characteristics, such as genders, learning styles or knowledge levels, in web-based learning performance is required. Finally, the learning approach was validated using sample data gathered from three elementary schools in Taiwan. The fact that the participants come from one country limits the generalizability of the results. Other samples from different countries and cultures should be collected to confirm and refine the findings of this study.

Acknowledgements

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### Appendix 1

#### Seven sets of constructive questions for problem-solving ability

<table>
<thead>
<tr>
<th>Set No.</th>
<th>Social issues</th>
<th>1st question</th>
<th>2nd question</th>
<th>3rd question</th>
<th>4th question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Credit Card Slave</td>
<td>How many credit card slaves are there in Taiwan?</td>
<td>What leads them to become card slaves?</td>
<td>What disadvantages and advantages are there when shopping with a credit card?</td>
<td>If you had a credit card, how would you use it to avoid becoming a card slave?</td>
</tr>
<tr>
<td>2</td>
<td>Renewable energy</td>
<td>What are the three forms of power generation used in Taiwan?</td>
<td>In addition to the previous methods, what other methods are there? Give a short introduction to each.</td>
<td>What are the disadvantages and advantages of nuclear power and thermal power?</td>
<td>If you were the Minister of Energy, what form of power generation would you adopt, and why?</td>
</tr>
<tr>
<td>3</td>
<td>Greenhouse effect</td>
<td>What countries are the top two carbon dioxide emitters in the world?</td>
<td>What are the impacts on the Earth of the emission of lots of carbon dioxide?</td>
<td>What solutions can decrease carbon dioxide emissions in life? What can you do?</td>
<td>If you were the Minister of Environmental Protection, what would you do to lower carbon dioxide emissions?</td>
</tr>
<tr>
<td>4</td>
<td>Garbage problem</td>
<td>What are the impacts on the Earth if lots of rubbish is produced? e.g. water, air, soil, etc.</td>
<td>What are three main methods of waste disposal? How do they work?</td>
<td>What are the differences among “landfill,” “garbage incineration,” and “recycling”?</td>
<td>What waste disposal method would you accept to decrease the garbage problem?</td>
</tr>
<tr>
<td>5</td>
<td>Water shortage</td>
<td>How many liters of water are used on average per day in Taiwan?</td>
<td>The annual rainfall exceeds 2,500mm in Taiwan, but there is still a water shortage, why?</td>
<td>Do you think the construction of reservoirs can solve water shortages in southern Taiwan? What impact would they have?</td>
<td>What specific actions can you take to help conserve water at school, at home or anywhere else?</td>
</tr>
<tr>
<td>6</td>
<td>Falling birthrate problem</td>
<td>Please find out the birthrate in 1979 and 2009 in Taiwan.</td>
<td>Currently, what is contributing to the falling birthrate problem in Taiwan?</td>
<td>What industries can be affected by the low birthrate problem?</td>
<td>If you were the President or Premier, what policy would you advocate to promote the birthrate?</td>
</tr>
</tbody>
</table>