Critical Factors Influencing Problem-Solving Ability in Online Learning Environments*

Seong Ik Park
Seoul National University

Seon-young Jang**
Seoul National University

Abstract

The purposes of the present study were to investigate the factors influencing problem solving ability skills in an online learning environment and to figure out which of these factors were significantly related to problem solving ability. Surveyed were 273 undergraduate students taking an 'educational technology' course at National Open University in Seoul, Korea. Based on the results of literature review, validation by experts and factor analysis, 46 items were developed.

The results were as follows: First, exploratory factor analysis showed eight factors influencing problem-solving ability in an online learning environment. Second, multiple regression showed that the first four factors among the eight factors (learners' cognitive strategies, learners' meta-cognitive strategies, providing necessary resources and tools for problem solving in an online learning environment, and learners' self-confidence in problem solving) were significant predictors of problem solving ability. The results showed that learners' cognitive strategies are the most closely related to problem-solving ability. This result implied that online learning environments should provide learners with supports to consider a goal and sub-goals of problem-solving and to break down big problem-solving tasks into sub-goals.

Key words: problem solving, problem solving ability, online learning environments, factor analysis, multiple regression

---

* The first and second authors currently participate in the『Brain Korea 21 Division of Competency-based Education Innovation』project.

** Corresponding author(hera0210@snu.ac.kr)

Ⅰ. Introduction

The society based on information and technology increasingly relies on someone who can apply knowledge and skills to solve daily problems as well as professional problems in a given area (Clark & Mayer, 2003). This trend demands a new educational perspective that stresses the importance of problem solving ability in education. Moreover, one of the most important goals of education is to enhance learners' abilities to solve real-world problems (Choi, 1999; Davis & Linn, 2000; Jonassen, 2000) because real-world problem solving is fundamental to higher-order thinking (Chang, Barufaldi, Lin, & Chen, 2007).

In addition, as the web becomes a powerful, interactive environment for distance learning, there has recently been more emphasis placed on the issue of developing problem solving abilities in online learning environments (Park & Jang, 2008; Phye, 2001). Online learning environments let learners access networked technology to find and manage information; build knowledge; and interact with peers, instructors and experts (Chou & Tsai, 2002; Schutt, 2003).

However, many studies have shown that learners have some difficulty successfully solving a problem in an online environment because of the communication delay, feelings of isolation, and other factors (Jonassen, 2004; Sharma & Hannafin, 2007; Simpson, 2000). In addition, learners who are familiar with and feel comfortable in a face-to-face classroom setting have difficulty while they are learning in the very different setting of online environments (Schutt, 2003; Woo & Park, 1999).

In this overall perspective, designing supportive online learning environments is a critical issue for improving learners' problem solving ability. Schutt (2003) demonstrated that, when designing online learning environments, it is worthwhile to ask whether learners have the physical, technological, and other prerequisite skills to succeed in online learning; whether an online learning environment provides clear directions about the process; and whether there are enough available resources for guidance and support.

To sum up, as the enhancement of problem solving ability becomes a main goal of education, and as online learning gains acceptance as an appropriate learning environment for learners to be successful problem-solvers, the need to provide instructional support becomes a crucial issue.

To design online learning environments that provide enough support for learners to develop problem solving competencies and confidence, one must explore the question of which factors influence problem solving ability. According to Burt (2005), problem solving comprises many factors that theoretically influence the solving of real-world problems; thus, it is necessary to understand whether and how these influential factors that possibly influence on problem solving abilities are related. For these reasons, we will investigate which factors ought to be considered essential to supporting learners' problem solving when designing online learning environments.

The purpose of this study is to explore the knowledge base in problem solving so that the goal of problem solving can be achieved by determining the factors that may influence problem solving abilities in online learning environments. Another purpose of this study is to investigate the highest possible multiple correlation of these factors with problem solving ability. According to the results of this study, it may be possible to draw some implications about how to support learners' problem solving in an online learning environment. That is, by identifying the relationships between these factors and problem solving ability, instructors or instruction designers can get prescriptive information to ensure that all learners are able to improve their problem solving abilities.

Research questions

1. What are the factors that influence problem solving ability in an online learning environment?
2. What is the highest possible multiple correlation of these factors with problem solving ability in an online learning environment?

Ⅱ. Theoretical background

A. The rationale for problem solving in online learning environments

A problem is "a situation in which you are trying to reach some goals, and must find a means for getting there" (Chi & Glaser, 1985). Regardless of the specific characteristics of the problem, all problems have an initial state of the learner's current level of knowledge. Problems have goals that the learner is trying to achieve. Most problems also require the solver to break these goals into sub-goals that result in goal achievement (Anderson, 1990; Chi & Glaser, 1985). Jonassen (2004) noted that a problem is an unknown entity in some context in which the difference between a goal state and a current state is one of the significant attributes of the problem. Learners often encounter what are called ill-structured problems, which are complex, ill-defined problems that learners encounter in everyday life (Tan, 2000).

The ability to solve ill-structured problems entails that problem solvers learn to think differently and flexibly enough where they focus on memorization and understanding (Jonassen, 2004). To solve problems, it can also be necessary to perceive the problem creatively. Ge (2001) reported that the ability to problem-solve is consists of presenting the problem, developing a solution, making justifications for the proposed solution, and monitoring and evaluating the problem solving process and the solutions.

As problem solving abilities have been demanded by today's learners (Uden & Beaumont, 2006), the most salient issues in ill-structured problem solving have been increasingly emphasized in education (Bardwell, Monroe, & Tudor, 1994; Jonassen, 1997). Rapid advances in technology and an expanding body of knowledge require learners to think critically. Learners also need to be able to think critically in order to solve a problem like professionals in their field and to link their knowledge to real-life situations (Park & Jang, 2008; Uden & Beaumont, 2006).

This calls for reform in learning environments because the traditional learning environment is not preparing learners for problem solving.

An online learning environment is one of the most appropriate learning environments for learners to improve their problem solving ability (Jang, 2005; Leem, 1999; Park & Jang, 2008). The Internet and computer networks provide opportunities for problem solving as learning. According to Shank (2007), the Internet has made it possible to share documents, help, and resources beyond the limitations of time and space; to offer widely accessible and continuing instruction and support rather than time-limited instruction; to expand access to learning experiences; and to augment face-to-face learning with additional tools and resources.

B. Comprehensive analysis of influential factors on problem solving

Many studies (e.g., Burt, 2005; Choi & Lee, 2009; Ge & Land, 2003; Jonassen, 2000) addressing problem solving have presented that various factors, including the learner, the online environment, the problem, tutors, and peers influence on problem solving ability. A comprehensive review of all the factors mentioned in previous studies is included below.

First, the learner factor among others for education has often been stressed in previous studies (Clark & Mayer, 2003; Kim, 2005; Mayer, 1998; Roh, 2007; Sternberg, 1984). In addition, learner’s psychological characteristics that can affect learners’ problem solving abilities are cognitive skills, meta-cognitive skills, self-confidence, and Information and Communication Technology (ICT) literacy.

1) Successful problem solving depends on cognitive skills. Mayer (1998) examined the effects of cognitive skills on problem solving. One of the cognitive skills necessary to generate a solution is the ability to break down subjects into instructional objectives. The other necessary skill is that of task analysis, which generates a hierarchy of subtasks within the problem

solving task. Cognitive skills also encompass to know how to coordinate and control of cognitive components, such as encoding, inferring, and applying information to problem solving. In addition, Clark and Mayer (2003) mentioned that success in problem solving relies on cognitive skills that include using facts, concepts, and procedures.

2) Meta-cognitive skills are considered one of the main factors influencing problem solving (Cho & Kim, 2006; Heppner, Neal, & Larson, 1984; Jonassen, 1997; Kim, 2000). Meta-cognitive skills are the ability to plan, monitor, and assess activity connected to problem solving (Clark & Mayer, 2003; Mayer, 1998). Sternberg (1984) studied the components of intelligence, noting the existence of a category he calls meta-components, which can be described as the reflective thinking processes surrounding planning and decision making in task performance. For example, the process of discovering what problem needs to be solved and deciding on a specific strategy to solve it are both meta-components. Cho and Kim (2006) commented that solving an ill-structured problem requires planning, monitoring, and evaluation. In addition, Moore's study (1995) on information problem solving found that learners continuously use multiple meta-strategies, such as monitoring outcomes of a solution and reflecting on the nature of the task.

3) Confidence has also been studied as a factor in relation to problem solving (Foshay, 2003; Heppner & Baker, 1997; Mayer, 1998). Foshay (2003) reported that confidence is a main source of successful problem solving. He concluded that 'the belief I can' is essential for a learner to solve a problem. Similarly, Heppner and Baker (1997) developed a study on a problem solving inventory to measure problem-solvers' confidence. They presumed that when learners face with a difficult problem like an ill-structured problem, it is hard for them to solve that problem without maintaining their confidence in their problem solving ability. In other words, confidence of problem solving abilities can be a main source of determination to solve the problem successfully.

4) As a number of studies have emphasized the need for

effective online learning environments, learners' literacy in ICT may contribute to improve their problem solving ability (Smeets, 2005). ICT literacy has been defined as "using digital technology, communications tools, and/or networks to access, manage, integrate, evaluate and create information in order to function in a knowledge society" (ETS, 2002). Markauskaite (2007) commented that ICT literacy and problem solving cover similar areas. By exploratory factor analysis, he found that ICT literacy could be divided into three factors: basic ICT capabilities, analysis and production of ICT capabilities, and information and Internet -related capabilities. In addition, Park and Chae (2002) stressed that learners must have ICT literacy before they can solve a given problem in an online learning environment. For these reasons, learners' ICT literacy is one of the factors influencing problem solving in an online environment.

Second, an online learning environment as a support system can provide the necessary resources and tools to guide problem solving. Therefore, the learning environment itself can be one of the factors influencing problem solving. Through problem solving, learners can construct their knowledge based on their experiences and can acquire more problem solving skills. Learners require learning environments to engage in active knowledge construction (Smeets, 2005). In this sense, learners need to search for available resources, to interact with experts in their own field, and to get others' help to solve a problem successfully. As such, an online learning environment has various functions that support learners' problem solving activities.

Third, the tutor's role is perceived as being important in problem solving (Grave, Dolmans, & Vleuten, 1998; Kang & Shin, 2008). Grave and his colleagues' study (1998) on the development of a tutor intervention profile shows that a tutor's roles in problem solving are that of elaboration, directing the learning process, integrating knowledge and stimulating interaction and individual accountability. Kang and Shin (2008) have developed a measuring instrument to play the role of a tutor in an online environment. In their study, the items were divided into four categories as tutors' role: experts in learning content and in evaluation; motivation and interaction facilitators; guidance for learning processes and methods; and system and community operators. In short, both studies showed that tutors are essential for learners to solve problems.

Fourth, many studies have shown that peer interactions provided advantages over interactions between instructors and learners. Park and Jang (2008) emphasized that peers interacted with one another by providing various scaffoldings during problem solving in an online environment. More specifically, learners were able to solve the given problem successfully because of their peers' help. In addition, Graesser and Person (1994) revealed that peers interact with each other more frequently during tutoring sessions than in a classroom setting, where interactions are primarily between an instructor and learners. In this sense, learners can learn constructively through peer interactions by being guided to reflect on problem solving processes and by asking one another for help and feedback. These studies confirmed that the support of peers is necessary for problem solving.

Fifth, real-world problems are often complex and ill-structured and differ from well-structured problems in numerous ways (Cho, 2001; Ge, 2001). Ill-structured problems are the sort of problems that are encountered in learners' everyday lives. These problems need to be addressed in an instructional context, where teachers should motivate learners to engage in knowledge construction (Smeets, 2005). Further, learners have to develop critical thinking abilities naturally by tackling ill-structured problem solving activities. According to Luszcz (1989), ill-structured problems have certain characteristics in common: goal achievement is more complex and less explicit; instructions alone provide insufficient information for solving the problem; the extent of relevant information is vague; and the problem solving process is not predictable. Solving an ill-structured problem is not easy for novice learners. Therefore, learners can attain the thinking ability of experts by practicing solving problems. In this sense, the characteristics of the problem itself may be one of the factors influencing problem solving.

Ⅲ. Methods

A. Participants

The 307 participants were sampled from undergraduate students enrolled in an 'educational technology' course at Korea's National Open University in Seoul who were asked to answer the questionnaire. However, 34 participants' responses were discarded because of missing data or insufficient responses, leaving 273 participants whose responses were evaluated through factor analysis and multiple regression. Among the participants, 37 (13.6%) were male and 236 (86.4%) were female. Because of the characteristics of the Open University, all participants had easy access to computers and the Internet outside the university. All of the students were accustomed to completing tasks and solving problems in an online learning environment.

B. Questionnaire I: factors influencing problem solving ability

In the first phase, all the items were developed from a review of the literature on problem solving (e.g., Burt, 2005; Choi, 2004; Egbert, 2009; Ge, 2001; Jonassen, 2004; Kang & Shin, 2008; Markauskaite, 2007; Tan, 2000; Zhang, 2004). In all, researchers developed 142 items. Several items pertaining to the learner are stated in general terms, phrased as an "I" statement. For example, one of the items addressing learners' self-assessment of cognition was phrased in the following way: "I selected and organized relevant information to solve the test questions". In contrast, other items that are directly related to other people or things (including factors related to the problem or to online learning environments) are phrased in the third person; for example, "Peers need to direct other learners' attention to the relevant features of a problem they do not understand".

In the second phase, researchers asked five experts (two doctors and three Ph.D. candidates in the field of problem solving) to screen the items relevant to problem solving. In more detail, experts were asked to find the redundant/unrelated items to problem-solving using a five-point Likert scale. As a result of this phase, 127 items were selected out of the 142 items from the first phase. The same five experts were then asked to check the items according to a five-point Likert scale of each item. 54 items earning less than three points on this scale were deleted, leaving a total of 73 items.

According to Stevens' suggestion (2002) that loadings with significance values greater than 0.4 represent substantive value, 25 of the 73 items were shown to be factor-loading, with values of less than 0.4. Further, according to Greens, Salkind, and Akey's suggestion (2000) that factors loading onto two items should be deleted, two items out of 73 items were deleted. Thus, 46 items were finally selected for categorizing the factors relevant to problem solving.

With these 46 items, 5 college students with experience in problem solving in an online environment were asked to proofread the questionnaire in order to check whether these items were understandable. As a result of this process, 10 items were restated for clarification. A five-point Likert scale was applied to measure the degree to which each item affected problem solving.

C. Questionnaire II: Problem solving ability

Our instrument for determining problem solving ability was taken from Ge's study (2001). This instrument is a self-reported questionnaire on problem solving skills that was developed based on work by Schoenfeld (1985) and Hong (1998). The questionnaire consists of 20 statements grouped into four areas: interpreting and problem representation; developing solutions and monitoring solution processes; making justifications; and evaluating the problem solving process. This instrument was verified by the same experts who were involved in verifying the items for factor analysis. Of these 20 statements, 5 items were judged by the experts to be repetitious and were deleted, leaving

15 items in all.

The most reliable way to validate participants' responses to each question about their problem solving ability is to take the self-assessment on each item, according to self-efficacy theory (Bandura, 1997). A large number of studies reported that self-efficacy is a strong predictor of behavior (Bandura, 1997; Hwang, 2005; Maddux, Norton, & Stoltenberg, 1986; Markauskaite, 2007; Rha & Lee, 2009). Bandura (1997) suggested that self-efficacy is a belief system related to problem solving, with behavior and solutions as outcomes. According to him, 'perceived self-efficacy refers to belief in one's capabilities to organize and execute the courses of action required to produce given attainments'. That is, learners make judgments about their problem solving ability to solve a given problem in order to accomplish a desirable outcome. Then, based on their judgment, they continue to engage in those problem solving behaviors. In particular, if learners believe they can solve a very difficult problem, there is a high probability that they will indeed solve that problem. The expectation about their problem solving ability determines whether or not the learner will succeed in solving a problem. Markauskaite (2007) insisted that self-assessment on problem solving and the results of self-assessment are as important as the results of an instructor's assessment on problem solving.

In more detail, many studies use performance measures for learners' self-reported results. Berdie (1971) reported the negative effect of test and studied intercorrelations between the test score and the self-rating score. In his study, the correlations ranged from .47 to .74. In addition, Pohlmann and Beggs' (1974) study on the reliability and validity of self-reported measures of academic growth showed that the coefficients between self-reported growth in attitudes and posttest attitude score were significantly greater than zero in each class. Evidently, there is a moderately significant positive correlation between self-reports and test score. These results are supported by Pike (1996): After many follow-up studies on this subject, he concluded that self-reports on learning and academic improvement can work as proxies for more traditional measures of learner achievement.

For these reasons, a self-assessment to measure learners' problem solving abilities was conducted based on the theory of self-efficacy in this study.

D. Data analysis

To answer the research questions, the data analysis was carried out as following procedures.

First, Exploratory Factor Analysis (EFA) was conducted, and the factors influencing problem solving ability in an online learning environment were identified. As one of the research questions was to explain what factors affect problem solving in an online learning environment, the Principal Component Analysis (PCA) method was used. The factors were rotated using a Varimax rotation procedure because this is the opposite in that it efforts maximize the dispersion of leading within factors. Therefore, it attempts to highly load a smaller number of variables onto each factor, resulting in more interpretable clusters of factors (Field, 2009).

Second, Multiple Regression was conducted to predict problem solving ability from a combination of several factors identified through the EFA. For this purpose, we used the method SPSS calls Enter (often called simultaneous regression) to consider all the factors as variables at the same time (Leech, Barrett and Morgan, 2005).

Ⅳ. Results

The mean score for eight problem solving ability factors on 46 items was between 'neither disagree nor agree' and 'agree' (M=3.48, SD = .36). Skewness is less than 2.5, and kurtosis is less than |1| (refer to Table 1, columns 5 - 6). These results show that the data are distributed approximately normally (Leech, et al., 2005).

The participants agreed with the statement that an online environment is extremely important for developing problem solving ability (M=4.04, SD = .53), whereas they negatively assessed that ICT literacy may less influence their problem solving abilities (M= 2.73, SD = .84) (refer to Table 1).

Table 1. Descriptive statistics of eight factors influencing problem solving ability

(N = 273)

Factors	No. of items	Mean*	SD	Skewness	Kurtosis
1. Learner's ICT literacy	11	2.73	0.84	0.21	-0.18
2. Providing necessary resources and tools for problem solving in an online learning environment	7	4.04	0.53	-0.02	-0.12
3.Peer/instructor's monitoring and feedback	7	3.22	0.68	-0.02	0.27
4.Learners' self-confidence of problem solving	4	3.22	0.58	-0.11	0.27
5. Problem's characteristics	6	3.88	0.56	-0.14	0.30
6. The enhancement of learners' motivation and interaction from tutor	3	4.04	0.63	-0.07	-0.15
7. Learners' meta-cognitive strategies	5	3.63	0.43	-0.15	-0.20
8. Learners' cognitive strategies	3	3.09	0.67	-0.12	0.21
Total	46	3.48	0.36	0.19	-0.04

* Mean = average score among all participants' responses on a five-point Likert scale for each factor composed of a number of items

A. Identification of the main factors influencing problem solving

The raw data were tested to determine whether factor analysis would be appropriate or not (refer to Table 2). Bartlett's test should be significant (Snedecor & Cochran, 1980); for example, it should have a significance value of less than .05 (Leech, et al., 2005). This means that the variables are correlated highly enough to provide a reasonable basis for factor analysis. For these data, Bartlett's test was highly significant ($p < 0.000$), and therefore, factor analysis is appropriate.

PCA with orthogonal rotation (Verimax) was conducted. The Kaiser-Meyer-Olkin (KMO) measure verified the sampling adequacy for the analysis (KMO =. 875, 'great' according to Field (2009)). The KMO measure should be greater than .70, and it is inadequate if less than .50 (Leech, et al., 2005). The KMO test reveals whether enough items are predicted by each factor. For these data, the KMO value was .875. Thus, we should be confident that factor analysis is appropriate for these data. Bartlett's test of sphericity indicated that the correlations between items were sufficiently large for PCA (= 8,177.392, p < .000) (refer to Table 2).

Table 2. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.875
Bartlett's Test of Sphericity	Approx. Chi-Square	8,177.392
	df	1,128
	Sig.	0.000

An initial analysis was run to obtain eigenvalues for each component in the data. Eight components had eigenvalues over Kaiser's criterion of 1, and in combination, these components explained 62.6% of the variance (refer to Table 3). In more detail, the first factor accounted for 15.0 % of the variance, the second factor accounted for 10.1%, the third factor accounted for 9.7%, the fourth factor accounted for 5.9%, the fifth factor accounted for 7.4%, the sixth accounted for 4.6%, the seventh factor accounted for 5.4%, and the eighth factor accounted for 4.5%. Table 3 shows the items and factor loadings for the rotated factors, with loadings less than .40 omitted to improve clarity.

According to Lee's suggestion (2006), the factors named through EFA were chosen to select the most well-defined and representative items based on a discussion with two problem solving experts. Eight factors were described: (1) the learner's ICT literacy, (2) providing necessary resources and tools for problem solving in an online learning environment, (3) monitoring and feedback from instructors and peers, (4) learners' self-confidence in problem solving, (5) the problem's authenticity and ill-structedness, (6) the enhancement of learners' motivation and interaction from tutors, (7) learners' meta-cognitive strategies, and (8) learners' cognitive strategies.

Table 3. Results of factor analysis for all items: average score and factor loadings for the rotated factors

(N = 273)

Component (Factor)	Items*	M	SD	Component (Factors) 1	2	3	4	5	6	7	8
1. Learner's ICT literacy	1. When I solve ill-structured problems, I design and manipulate my own databases (e.g., to add the files and to generate reports. etc.)	2.86	1.10	0.839							
	2. When I solve ill-structured problems, I manipulate data and solve various problems using spreadsheets (e.g., to combine and analyze data by drawing various charts etc.)	2.63	1.13	0.834							
	3. When I solve ill-structured problems, I design presentations with multimedia elements (e.g., to add sounds, and graphics etc.)	2.41	1.14	0.832							
	4. When I solve ill-structured problems, I perform advanced document formatting tasks (e.g., to create columns etc.)	3.20	1.09	0.823							
	5. When I solve ill-structured problems, I edit and design graphics (e.g., to edit scanned picture, apply graphics effects, etc.)	2.29	1.07	0.822							
	6. When I solve ill-structured problems, I perform basic tasks common to many software applications (e.g., to save a file in a specified format and location etc.)	3.36	0.96	0.807							
	7. When I solve ill-structured problems, I use planning and decision-support tools (e.g., to use idea mapping and project design tools.)	2.32	1.03	0.768							
	8. When I solve ill-structured problems, I search and gather information from the Internet and other digital resources (e.g., to use appropriate search engines etc.)	3.40	1.04	0.760							
	9. When I solve ill-structured problems, I evaluate the relevance and quality of digital resources and information (e.g., to determine whether information is current, accurate and reliable.)	2.97	0.98	0.757							
	10. When I solve ill-structured problems, I create a basic web page (e.g., to create a web page using web page creation tools, to add text, tables and graphics, insert hyperlinks)	2.03	0.97	0.734							
	11. When I solve ill-structured problems, I publish and deliver the results of a research activity using ICT presentation tools and networks (e.g., to use discuss forum, etc.)	2.58	1.08	0.708							

2. Providing necessary resources and tools for problem solving in an online learning environ-ment	12. An online learning environment needs to provide information and skills of problem solving process.	4.06	0.64		0.820						
	13. An online learning environment needs to useful resource for guiding problem solving process.	4.13	0.62		0.820						
	14. An online learning environment needs to provide resources to help for learners how to solve.	4.11	0.63		0.790						
	15. An online learning environment needs to authentic resources.	3.98	0.65		0.769						
	16. An online learning environment needs to provide resources to write the result of problem solving.	4.04	0.68		0.767						
	17. An online learning environment needs to provide tools which help to organize the knowledge that I know by integrating information into some framework for example, concept mapping tool.	3.86	0.77		0.679						
	18. An online learning environment needs to provide tools to stimulate interaction between instruction and me.	4.06	0.62		0.659						
3. Peer/ instructor's monitoring and feedback	19. Peer needs to be able to explain concepts in familiar terms	3.22	0.85			0.839					
	20. Peers need to provide them with multiple perspectives and lead them to see things that might have overlooked.	3.23	0.83			0.836					
	21. Peer interactions are articulating one's thoughts.	3.14	0.83			0.810					
	22. Peers need to ask questions which will challenge one's thinking and require explanations, elaboration, reflective feedback, different ideas, expertise, and perspectives can be generated from the member.	3.06	0.78			0.809					
	23. Though interactions, such as questioning, explanations, elaboration and reflective feedback, different ideas, expertise, and perspectives can be generated from the members.	3.13	0.93			0.793					
	24. Peers need to be able to direct other student's attention to the relevant features of a problem they do not understand	3.29	0.79			0.746					
	25. Instructors need to check my process of problem solving.	3.49	0.90			0.567					

4. Learners' self-confidence of problem solving	26. I can solve any kind of problem when I am in strange situation.	3.24	0.80				0.754				
	27. I believe that I can follow to my plan, when I make a plan to solve a problem. ?	3.42	0.73				0.723				
	28. I can make creative and effective alternatives when I have some difficulty.	3.14	0.81				0.711				
	29. I am interested in problems that I can face this problem in daily life.	3.40	0.78				0.704				
5. Problem's authenti-city and ill-structured-ness	30. Problems need to be faced in a real daily life.	3.79	0.75					0.837			
	31. Problems need to contain the authentic case.	3.74	0.75					0.815			
	32. Problems need to ask for my natural process of thinking.	3.84	0.73					0.800			
	33. Problems need to have various solutions.	3.99	0.64					0.656			
	34. Problems need to ask for me to think of expert's way of thinking. ?	3.35	0.94					0.593			
	35. Problems need to lead learner-centered activities.	4.05	0.62					0.458			
6. The enhance-ment of learners' motivation and interaction from tutor	36. Instructors need to reply on my texts.	3.99	0.77						0.859		
	37 Instructors need to reply on my e-mail.	4.09	0.69						0.840		
	38. Instructors need to encourage for me to keep solving the problem.	4.04	0.78						0.651		

7. Learners' meta-cognitive strategies	39. I determine how to solve the test questions	3.56	0.77							0.689	
	40. I select and organized relevant information to solve the test questions.	3.40	0.78							0.664	
	41. I keep track of my progress and, if necessary, I change my techniques or strategies.	3.41	0.80							0.617	
	42. I try to find out the key-point when I have some difficulty.	3.75	0.73							0.600	
	43. I correct my error when I find something wrong during problem solving	3.67	0.70							0.519	
8. Learners' cognitive strategies	44. I make a hierarchy of subtasks involved in any problem solving task.	2.86	0.90								0.822
	45. I orchestrate and control the cognitive components in any problem solving task such as encoding, inferring, and applying.	3.00	0.80								0.696
	46. I think the goal during problem solving and break the big task down into according to the goal.	3.41	0.77								0.616
Eigen Values				7.181	4.826	4.678	2.849	3.535	2.217	2.605	2.156
% of Variance				14.961	10.053	9.746	5.936	7.364	4.619	5.427	4.491
Cumulative % of Variance				14.961	25.014	34.760	48.060	42.124	58.106	53.487	62.597

* A five-point Likert scale was applied to measure to what degree each item had an effect on problem solving: 1= strongly disagree, 2= disagree, 3=neither disagree nor agree, 4= agree, 5=strongly agree.

Cronbach’s alpha was calculated to assess whether the 46 items that were summed to find the factors influencing problem solving abilities formed a reliable scale. The alpha for the 46 items was 0.92, which indicated that the items form a scale that has reasonable internal consistency reliability (refer to Table 4). All of problem solving factors had high reliability: all Cronbach’s alphas were more than .6. Specifically, the alpha for the items in the factor pertaining to learners’ ICT literacy was .94. However, the .69 alpha for the ‘learners’ cognitive strategies’ indicated minimally adequate reliability (Leech, et al., 2005).

Table 4. Reliability coefficient of eight factors influencing problem solving ability

Factor	N of Items	Cronbach's Alpha	Cronbach's Alpha based on Standardized Items
1. Learner’s ICT literacy	11	0.94	0.94
2. Providing necessary resources and tools for problem solving in an online learning environment	7	0.83	0.85
3. Peer /instructor’s monitoring and feedback	7	0.91	0.90
4. Learners’ self-confidence of problem solving	4	0.81	0.81
5. Problem’s authenticity and ill-structuredness	6	0.85	0.86
6. The enhancement of learners’ motivation and interaction from tutor	3	0.79	0.79
7. Learners’ meta-cognitive strategies	5	0.76	0.75
8. Learners’ cognitive strategies	3	0.69	0.69
Total	46	0.92	0.92

B. Determining the best linear combination of the eight factors

Multiple regression analysis was conducted to determine the best linear combination of the eight factors that predicts problem solving abilities. The means, standard deviations, and inter-correlations can be found in Table 5.

Table 5. Means, Standard Deviations, and Intercorrelations for problem solving ability and the eight factors

(N = 273)

		M	SD	1	2	3	4	5	6	7	8
Dependent Variable	Problem solving ability	3.38	0.52	0.21	0.24	0.20	0.49	0.25	0.15	0.61	0.65
Predictor Variable	1.Learner's ICT literacy	2.73	0.84								
	2. Providing necessary resources and tools for problem solving in an online learning environment	4.04	0.53	0.19*							
	3. Peer/instructor's monitoring and feedback	3.22	0.68	0.14*	0.35*						
	4.Learners' self-confidence of problem solving	3.22	0.58	0.22*	0.14*	0.17*					
	5.Problem's characteristics	3.88	0.56	0.15*	0.52*	0.36*	0.25*				
	6. The enhancement of learners' motivation and interaction from tutor	4.04	0.63	0.16*	0.36*	0.33*	0.16*	0.31*			
	7. Learners' meta-cognitive strategies	3.63	0.43	0.23*	0.25*	0.16*	0.46*	0.34*	0.21*		
	8. Learners' cognitive strategies	3.09	0.67	0.22*	0.03	0.15*	0.47*	0.13*	0.03*	0.44	

This combination of variables significantly predicted problem solving ability: $F(8, 264) = 45.06$, $p < .00$, with all variables significantly contributing to the prediction (refer to Table 6).

Table 6. Simulated Multiple Regression Analysis Summary for the eight factors predicting problem solving ability

Component (Factor)	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	0.04	0.23		0.18	0.86		
1. Learner's ICT literacy	-0.01	0.03	-0.02	-0.47	0.64	0.90	1.12
2.Providing necessary resources and tools for problem solving in an online learning environment	0.13	0.05	0.14	2.75	0.01*	0.65	1.54
3.Peer/instructor's monitoring and feedback	0.02	0.03	0.02	0.54	0.59	0.78	1.28
4. Learners' self-confidence of problem solving	0.09	0.04	0.11	2.21	0.03*	0.68	1.47
5. Problem's characteristics	-0.03	0.05	-0.03	-0.65	0.51	0.64	1.56
6. The enhancement of learners' motivation and interaction from tutor	0.01	0.04	0.01	0.19	0.85	0.79	1.27
7. Learners' meta-cognitive strategies	0.40	0.06	0.34	6.77	0.00*	0.65	1.54
8. Learners' cognitive strategies	0.35	0.04	0.45	9.31	0.00*	0.68	1.46

* $p < 0.05$; N=273

R Square = 0.58	Adjusted R Square = 0.56
F = 45.06	p = 0.00

Tolerance and VIF (Variance Inflation Factor) indicate whether there was multicollinearity. If the tolerance value is lower than 1-, then there is probably a problem with multicollinearity (Leech, et al., 2005). In this case, because the adjusted was .56, all of the tolerances were well over .44(1-), meaning that multicollinearity was not a problem for this model.

The beta weights in Table 6 suggest that 'learners' cognitive strategies' contributes most strongly to predicting problem solving ability and that 'learners' meta-cognitive strategies', 'providing necessary resources and tools in an online learning environment', and 'learners' self-confidence in problem solving' also contribute to this prediction. The adjusted R-squared value was .56. This indicates that 56% of the variance in problem solving ability was explained by the model. Based on these results, ‘learners’ cognitive strategies’ (B=.45, t=9.31) was most strongly related to the problem solving ability. The other three factors were strongly related to problem solving ability in ‘learners’ meta-cognitive strategies’ (B=.34, t=6.77), ‘providing necessary resources and tools for problem solving in an online learning environment (B=.14, t=2.75) and ‘learners’ self-confidence in problem solving’ (B=.11, t=2.21). These results suggest the importance of assisting problem solvers in their use of cognitive and meta-cognitive strategies. In addition, online learning environments must be designed so that problem solvers can solve the given problems successfully. Lastly, problem solvers need encouragement to develop their self-confidence.

Ⅴ. Conclusions and implications

The purpose of this paper has been to investigate the factors that are closely related to problem solving in an online learning environment and to find out which of these factors significantly affects learners’ problem solving abilities.

Using exploratory factor analysis, eight factors, listed here in order from most to least important, were identified: (1) learners’ cognitive strategies, (2) learners’ meta-cognitive strategies, (3) the presence of necessary resources and tools, (4) learners’ self-confidence in problem solving, (5) monitoring and feedback from instructors and peers, (6) the problem’s authenticity and ill-structuredness, (7) the enhancement of learners’ motivation and interaction from tutor, and (8) learners’ ICT literacy.

As a result of multiple regression analysis, four factors were identified as predictors to know the priority of factors as components, and relationships between these factors and problem solving ability. The first four factors listed above were found to be the most important factors affecting problem solving in online learning.

First, the most important implication of our findings is the necessity of helping learners use cognitive strategies while they solve a given problem. Our results show that the learner factor is the most related to problem solving ability. This result is confirmed with Kim's study (2005) on the factors influencing gifted and non-gifted learners' creative problem solving skills in science and with Lee and his colleagues' study (2007) analyzing the effects of learner factor on a creative problem solving program in an elementary school. These two studies show that use of domain knowledge in an appropriate way as a cognitive skill is one of the most significant predictors of creative problem solving skills. Based on the result of this study, it can be suggested that it is essential to support learners' cognitive skills in an online learning environment. In particular, online learning environments should help learners think about a goal during problem solving and break down the big problem solving task into sub-goals. A checklist that makes learners think about goals before solving the problem can be one support strategy (Barrows, 1988). In addition, it is also necessary to make the case for using cognitive strategies such as encoding, inferring, and applying and to provide guidelines for making a hierarchy of subtasks within a big problem solving task.

Second, support for meta-cognitive strategies is also necessary. The results of the regression analysis in this study showed that learners' meta-cognition is closely related to problem solving. This result has been verified in many studies (e.g., Ge & Land, 2003; Kim, 2000; Mayer, 1998; Moore, 1995) that emphasize that meta-cognition is an essential factor for successful problem solving. Thus, it can be suggested that an effective support strategy would be to help learners monitor their problem solving process. Kim (2000) also reported 'self-monitoring', which has been shown to be statistically correlated to three stages of the execution process of solving problems (collecting data, utilization of information, and creating information). In this sense, self-monitoring is a useful strategy to help learners learn how to solve the problem and organize relevant information to solve the problem.

Third, an implication of this study is the necessity of designing online learning environments that provides appropriate tools and resources. It is usually necessary to searching information or resources to solve an ill-structured problem (Barrows, 1988). However, because of the characteristics of ill-structured problems (which have vague goals, information, and directions), learners are usually faced with difficulties in trying to solve a given problem. In face-to-face instruction, teachers would normally help learners overcome these difficulties. However, it is not easy for instructors to provide learners with useful information. By comparison, online learning has many advantages. For example, online learning environments can provide access to a multitude of resources, and learners can interact with peers or experts by using chatting tools, e-mail, or bulletin boards (Hoffman & Ritchie, 1997; Leem, 1999). Even though online learning environments have many strong points, they may negatively influence problem solving for problem solvers who have little problem solving experience in online learning environments (Woo & Park, 1999). For this reason, an integral part of designing online learning environments should be easy access to tools and resources. More concretely, online environments must provide tools to help learners think about ideas and hypotheses, develop a solution, and reflect on what they have learned.

Fourth, learners' self-confidence in problem solving must be developed when designing an effective online learning environment for developing problem solving skills. This study has found that learners' self-confidence in problem solving is significantly correlated with their problem solving ability. It is more likely that learners will give up on a problem if they feel that they are not problem solving experts or if they face the problem at an early phase because the problem is ill-structured (Lee & Jang, 2009). In this sense, when learners feel frustrated during problem solving, it is important to encourage learners' problem solving activities and offer advice to overcome their discouragement. Providing 'frustration control' scaffolding with learning agency can be an effective support strategy (Wood, Bruner, & Ross, 1976). In addition, it is also necessary to provide the proper sequence of problems according to their complexity and difficulty (Pedaste & Sarapuu, 2006).

As mentioned in the results section, this study showed that learners' ICT literacy, monitoring and feedback from instructors and peers, the enhancement of learners' stimulation of motivation and interaction from tutors, and problem's authenticity and ill-structuredness are the factors which are not significantly related to problem solving ability. We offer at least three reasons for these outcomes. First, the participants in this study focused on problem solving itself, rather than recognizing the characteristics of the problem. In addition, they were not familiar with the characteristics of an ill-structured problem because they were not experts at problem solving. Second, the participants in this study were adult learners, so they considered their own self-confidence in problem solving to be a much more powerful factor than receiving help from peers or tutors. In addition, they were highly motivated to learn and to solve the problem. Thus, they regarded self-confidence as an important factor in problem solving. However, it would be an oversight to conclude that the factors noted above are not available factors. Even though these factors had a relatively low power value, these factors may still be well worth considering when designing online learning environments for problem solving.

Received in 30th September, 2010
Reviewed in19th November, 2010
Revised version received in 17th December, 2010

References

Anderson, J. R. (1990). Cognitive psychology and its implications. (3rd ed.) New York: Freeman.

Bandura, A. (1997). Self-efficacy: The exercise of control. New York: W. H. Freeman and Company.

Bardwell, L. V., Monroe, M. C., & Tudor, M. T. E. (1994). Environmental Problem Solving: Theory, Practice, and Possibilities in Environmental Education: NAAEE.

Barrows, H. S. (1988). The Tutorial Process (3rd ed.). Springfield IL: Sourthern Illinois University Press.

Berdie, R. F. (1971). Self-Claimed and Tested Knowldege. Educational Psychological Measurement, 31, 629-636.

Burt, K. G. (2005). Analysis of the factors involved in technological problem solving in a college technology education classroom. Unpublished doctoral dissertation, North Carolina State University.

Chang, C.-Y., Barufaldi, J. P., Lin, M.-C., & Chen, Y.-C. (2007). Assessing 10th-grade students' problem solving ability online in the area of Earth sciences. Computers in Human Behavior, 23, 1971-1981.

Chi, M. T. H., & Glaser, R. (1985). Problem-solving ability. In R. J. Stenberg (Ed.), Human abilities: An information-processing approach (p.227-250). New York: Freeman.

Cho, K. (2001). The effects of argumentation scaffolds on argument and problem solving in an online collaborative group problem-solving environment. Unpublished doctoral dissertation. Pennsylvania State University, Pennsylvania State.

Cho, K., & Kim, S. Y. (2006). The Effects of Cognitive Style and Metacognition on Ill-structured Problem Solving and Argumentation in an Individual Problem Solving Situation. The Journal of Educational Information and Media, 12(3), 5-32.

Choi, I., & Lee, K. (2009). Designing and implementing a case-based learning environment for enhancing ill-structured problem solving: classroom management problems for prospective teachers. Eudcational Technology Research and Development, 57, 99-129.

Choi, J. I. (1999). Problem Solving and Web Based Education. In I. J. Rha (Ed.), Web Based Education. seoul: Kooyookbook.

Choi, J. I. (2004). A study on the problem design principle for Problem-Based Learning through the case analysis. Journal of Educational Technology, 20(1), 37-61.

Chou, C., & Tsai, C. (2002). Developing Web-based curricula: Issues and challenges. Journal of Curriculum Studies, 34, 623-636.

Clark, R. C., & Mayer, R. E. (2003). e-Learning and the Science of Instruction. San Francisco: Pfeiffer.

Davis, E. A., & Linn, M. (2000). Scaffolding Student's Knowledge integration: Prompts for reflection in KIE. International Journal of Science Education, 22(8), 819-837.

Egbert, J. (2009). Supporting Learning with Technology. New Jersey: Pearson Education.

ETS. (2002). Digital transformaiton: A framwork for ICT literacy. A report of iInternational Information and communication technology proficies. . USA: Educational Testing Service.

Field, A. (2009). Discovering Statistics Using Spss. (3rd Ed.) London: SAGE.

Foshay, R. (2003). Principles for teaching problem solving. Indiana: PLATO Learning.

Ge, X. (2001). Scaffolding students' problem-solving processes on an ill-structured task using question prompts and peer interactions. Unpublished doctoral dissertation, Pennsylvania State University.

Ge, X., & Land, S. M. (2003). Scaffolding Students' Problem-Solving Processes in an ill-Structured Task Using Question Prompts and Peer Interactions. Educational Technology Research and Development, 51(1), 21-38.

Graesser, A. C., & Person, N. K. (1994). Question Asking during Tutoring. American Educational Research Journal, 31(1), 104-137.

Grave, W. S. D., Dolmans, D. H. J. M., & Vleuten, C. P. M. v. d. (1998). Tutor intervention profile; reliability and validity. Medical Education, 32, 262-268.

Green, S. B., Salkind, N. J., & Akey, T. M. (2000). Using SPSS for windows: Analyzing and understanding data. New Jersey: Prentice-Hall.

Heppner, P., & Baker, C. (1997). Applications of the problem solving inventory [Elecronic version] Measurement and Evaluation in Counseling and Development, 29(4).

Heppner, P. P., Neal, G. W., & Larson, L. M. (1984). Problem-solving traning as prevention with college students. Personnel and Guidance Journal, 62, 514-519.

Hoffman, B., & Ritchie, D. (1997). Using multimedia to voercome the problems with problem based learning. Instructional Science, 25, 97-115.

Hong, N. S. (1998). The relationship between well-structured and ill-structured problm solving in multimedia simulation. Unpublished doctoral dissertation, Pennsylvania State University, PA.

Hwang, S. Y. (2005). A Validation Study of the Problem Solving Inventory in the Career Decision Scale of Korean University Student. Unpublished master's dissertation. Yousei University, Seoul.

Jang, J. (2005). Development of online problem-based learning design model. Unpublished doctoral dissertation, Seoul National University, Seoul.

Jonassen, D. H. (1997). Instructional Design Models for Well-Structured and Ill-Structured problem-Solving Learning Outcomes. Educational Technology Research and Development, 45(1), 65-94.

Jonassen, D. H. (2000). Toward a design theory of problem solving. Educational Technology Research and Development, 48(4), 23.

Jonassen, D. H. (2004). Learning to Solve Problems: An Instrucional Design Guide. CA: Pfeiffer.

Kang, E., & Shin, J. (2008). Development of a Scale for Tutor's Role for Elementary Cyber Home Learning. Journal of Educational Technology, 24(2), 207-232.

Kim, M. (2005). The Factors Influencing Gifted and Nongifted Students' Creative Problem Solving Skills in Science. The Korean Journal of Educational Psychology, 19(2), 477-503.

Kim, R. (2000). A Study on the Correlation between Learner's Metacognition and Information Problem-solving Ability in Web-based Instruction Applying Information Literacy Model. Unpublished master's dissertation. Ewha Womans University, Seoul, Korea.

Lee, H., & Jang, S. (2009). Development Study of a Scaffolding Guideline for Improving Tutor's Performance in e-PBL. The Journal of Yeolin Education, 18(1), 67-96.

Lee, J., Koo, Y. M., Nam, M., Park, S., Kim, B., Park, D., et al. (2007). Analysis of Effects of Learner Factors on Creative Problem Solving Programs in Elementary School Social Studies. The Journal of Educational Information and Media, 13(1), 279-308.

Lee, Y. (2006). Identifying Variables that Affect Learner's Preference Toward E-Learning Program. The Journal of Korean Association of Computer Education, 9(3), 67-74.

Leech, N. L., Barrett, K. C., & Morgan, G. A. (2005). SPSS for Intermediate Statistics : Use and Interpretation. Mahwah, New Jersey: Lawrence Erlbaum Associates.

Leem, J. (1999). Effects of small-group cooperative learning strategies on learner participation in online discussion and problem solving in a web-based learning environment Seoul National University, Unpublished doctoral dissertation. Seoul, Korea.

Luszcz, M. A. (1989). Theoretical Models of Everyday Problem Solving in Adulthood. In J. D. Sinnott (Ed.), EVERYDAY PROBELM SOLVING: Theory and Applications. New York: Preager.

Maddux, J. E., Norton, L. W., & Stoltenberg, C. D. (1986). Self-efficacy expectancy, outcome expectancy, and outcome value: Relative effects on behavioral intentions. Journal of Personality and Social Psychology, 82,107-116.

Markauskaite, L. (2007). Exploring the structure of trainee teachers' ICT literacy: the Main components of, and relationships between, general cognitive and technical capabilities. Educational Technology Research and Development, 55(4), 545-572.

Mayer, R. E. (1998). Cognitive, metacognitive, and motivationl aspects

of problem solving. Instructional Science, 26, 49-63.
Moore, P. (1995). Information Problem Sovling: A Sider View of Library Skills. Contemporary Education Psychology, 20, 1-31.
Park, M., & Chae, J. H. (2002). Development of a Web Based Learning Environment for Problem Solving using ICT in Home Economics Education. Journal of the Korean Home Economics Association, 40(7), 69-82.
Park, S. I., & Jang, S. (2008). Analysis of peer-scaffolding patterns in four phases of problem-solving in web-based instruction. The SNU Journal of Education Research, 17, 1-30.
Pedaste, M., & Sarapuu, T. (2006). The Factors Influencing the Outcome of Solving Story Problems in a Web-based Learning Environment. Interactive Learning Environments, 14(2), 153-176.
Phye, G. D. (2001). Problem-solving instruction and probelm-solving transfer: The correspondence issue. Journal of Educational Psychology, 93(3), 571-578.
Pike, G. R. (1996). Limitations of using students' self-reports of academic development as proxies for traditional achievement measures Higher Education, 37(1), 89-114.
Pohlmann, J. T., & Beggs, D. L. (1974). A Study of the Validity of Self-Reported Measures of Academic Growth. Journal of Educational Measurement, 11, 115-119.
Rha, I., & Lee, J. (2009). Korean In-Service Teachers' ICT Literacy: the Main Components and the Structure of General Cognitive and Technical Capabilities. The Journal of Educational Information and Media, 15(4), 21-45.
Roh, S. (2007). Factors Influencing the Academic Achievements of Web-based Distance Learners: The Case of Capital Region's Undergraduate Distance Learners. The Journal of Educational Information and Media, 13(1), 99-130.
Schoenfeld. (1985). Mathmetical problem-solving. San Diego, CA: Academic Press.
Schutt, M. (2003). Scaffolding for Online Learning Environments: Instructional Design Stragegies that Provide Online Learner Support. Educational Technology, 43(6), 28-35.
Shank, P. (2007). The online learning idea book: 95 Proven Ways to

Enhance Technology-Based and Blended Learning. CA: pfeiffer.
Sharma, P., & Hannafin, M. (2007). Scaffolding in Technology-Enhanced Learning Environments. Interactive Learning Environments, 15(1), 27-46.
Simpson, O. (2000). Supproting Students in Open and Distance Learning: Stylus Publishing Inc.
Smeets, E. (2005). Does ICT contribute to powerful learning environments in primary education? Computers and Education, 44, 343-355.
Snedecor, G. W., & Cochran, W. G. (1980). Statistical Method.(7th Ed.) Ames, IA: Iowa State University Press.
Sternberg, R. J. (1984). Mechanisms of cognitive development: A componential approach. In R. J. Sternberg (Ed.), Mechanisms of cognitive development: NewYork: Cambridge University Press.
Stevens, J. P. (2002). Applied multivariate statistics for the social sciences. (4th ed.) Hillsdale, NJ: Erlbaum.
Tan, S. C. (2000). Supporting Collaborative Problem Solving through Computer-Supported Collaborative Argumentation. Unpublished doctoral Dissertation. The Pennsylvania State University.
Uden, L., & Beaumont, C. (2006). Technology and Problem-Based Learning Hershey: Information Science Publishing.
Woo, O., & Park, J. (1999). The Effects of PBL(Problem-Based Learning) on Problem Soving Process by Learner's Metacognitive Level. Journal of Educational Technology, 15(3), 55-81.
Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. Journal of Child Psychology and Psychiatry, 17, 89-100.
Zhang, K. (2004). Effects of Peer-Controlled or Externall Structured and Moderated Online Collaboration on Group Problem Solving Processes and Related Individual Attitudes in Well-Structured and Ill-Structured Small Group Problem Soving in a Hybrid Course. Unpublished doctoral dissertation. The Pennsylvania State University.