Pre-Service Elementary Teachers' Motivation and Ill-Structured Problem Solving in Korea

Min Kyeong Kim & Mi Kyung Cho
Ewha Womans University, SOUTH KOREA

This article examines the use and application of an ill-structured problem to pre-service elementary teachers in Korea in order to find implications of pre-service teacher education with regard to contextualized problem solving by analyzing experiences of ill-structured problem solving. Participants were divided into small groups depending on the levels of motivation. They participated in a five-step phase labeled A-B-C-D-E [Analyze/Browse/Create/Decision-Making/Evaluate] for problem solving. Result showed that the phase-specific analysis of ill-structured problem solving processes from the levels of motivation could decide the quality of their problem solving in subsequent phases.

Keywords: ill-structured problem solving, pre-service teacher, mathematics education, motivation

INTRODUCTION

PISA 2012, in international comparative studies of academic achievements, analyzed mathematical literacy regarding the mathematical process. The percentages of correct answers from Korean students resulting from the analyses were as follows: 'analyze' was the highest, at 61.34%, followed by 'use' at 60.51%, with 'formalize' in last place at 49.76 %. The percentages of correct answers for 'formalize' were lower than the others, revealing 46.87%, 48.77%, and 49.79% in the years 2003, 2006, and 2009, respectively. Consequently, there is a need for experiences in schools which can allow students to formalize mathematical problems from real contexts, rather than routine problems which are already mathematically-translated from real contexts (Song et al., 2013).

The elementary school mathematics textbooks in Korea have tried to build links between the various phenomena of everyday life and school mathematics by presenting 'Preparation' at the beginning of each lesson. However, it was found that

Correspondence: Min Kyeong Kim,
Ewha Womans University, 52 Ewhayeodae-gil, Seodaemun-gu,
South Korea.
E-mail: mkkim@ewha.ac.kr

the given situations were likely to be far from the real world (Kim, Park, & Heo, 2012). In addition, analysis of the mathematical problems from Korean and U.S. textbooks (Houghton Mifflin Mathematics, Connected Mathematics) from the ill-structured [I-S] point of view revealed that Korean textbooks tended to present structured problems, which did not aid students in the development of advanced skills (Kim, Lee, Hong, & Kim, 2011).

Meanwhile, teachers are required to figure out how much students understand and are interested in mathematics, how much experience they have with it, and how to present a wide range of assignments to help students learn mathematics better. Such assignments can enhance the mathematical problem solving and communication skills of students. Furthermore, they can also help students recognize mathematics as part of human activity (National Council of Teachers of Mathematics [NCTM], 1991). Mathematics education needs to be improved, and the process of teaching and learning must be changed to support the improvement of problem solving abilities. To accomplish this, I-S problems can be utilized. This is because I-S problems are contextualized from specific contexts, are more interesting and meaningful to learners, and encourage learners to define problems on their own and to determine the information and techniques necessary to solve problems (Chi & Glaser, 1985).

Auguste, Kihn, and Miller (2010) conducted research on the top three countries (Singapore, Finland, and Korea) which displayed high achievements in international comparative studies and on successful school systems to explore ways to promote teacher effectiveness, which raises student achievement. The research assumed that the quality of education systems is related to the quality of teachers. According to that study, the top 30 percent of Singaporean students, 20 percent of Finnish students, and 5 percent of Korean students, who showed high levels of achievement, became teachers. Therefore, Korea can be seen as having the world's highest level of teachers. However, these high level pre-service teachers had no experience with I-S problem solving, which is the most similar to experiences in the real world.

In addition, although teachers in the field indicated the need for inclusion of contextualized I-S problems in mathematics education, as they can give opportunities to find various solutions for a problem while improving the creative thinking skills or information processing abilities of students, the development and application proved to be very difficult in reality (Kim, Min, & Kim., 2011). As problem solving has been emphasized in mathematics curriculum both at home and abroad, discussions about how the mathematical problem solving process is taught and learned have been continuing. Polya (1981) observed the education of mathematics teachers over many years. Based on the observations made, he suggested a need for the systematic preparation of mathematics teachers and argued that reasonable answers to the question of "What should universities provide for pre-service mathematics teachers?" should be determined.

State of the literature

- Realistic situations relevant to student experiences should be given, and the mathematization of such situations should be materialized through various mathematical activities.
- Ill-structured problems, which are contextualized, more interesting and meaningful to learners, have various solutions or no solution at all, as one or more aspects of the problem situations are not well specified
- Motivation plays a big role in encouraging students to become interested and display the curiosity needed to support increased learning.

Contribution of this paper to the literature

- This study introduces an ill-structured problem solving process followed a five phase model called A-B-C-D-E (Analyze/Browse/Create/Decision-Making/Evaluate).
- In-depth analysis was conducted on the problem solving process depending on the levels of motivation of the groups.
- This study presents implications of pre-service teacher education with regard to contextualized problem solving by analyzing their experiences and motivation with I-S problem solving.

Based on the importance of research in this area, the present research aimed at finding implications of pre-service teacher education with regard to contextualized problem solving by analyzing experiences with I-S problem solving. To accomplish this, pre-service elementary teachers were divided into small groups depending on their levels of motivation, and the following research questions were set.

1. How much impact do the levels of motivation have on I-S problem solving abilities?
2. What are the characteristics of each phase of I-S problem solving depending on the levels of motivation?

BACKGROUND

Ill-structured problem solving and mathematics education

In recent mathematics education, there has been a growing interest in the application of mathematics to situations outside of school (Arcavi, 2002). According to Moschkovich (2002), everyday problems which have multiple solutions are different from common problems which can be seen in mathematics textbooks. In addition, everyday mathematics should be differentiated from academic mathematics, and it is important to connect everyday activities to the academic activities in a mathematics classroom. Realistic situations relevant to student experiences should be given, and the mathematization of such situations should be materialized through various mathematical activities.

The mathematical knowledge that students learn needs to be relevant to their real lives, through which they can be encouraged to learn and understand the basic concepts and principles faithfully. It must give students the opportunity to experience and solve problems which are based on their lives. Therefore, to ensure that school curriculum helps students solve real world problems, the mathematics classroom should utilize I-S problems, whose situations allow for various solutions just like in real world situations. By doing so, the mathematics classroom could contribute to helping the students to actively solve problems that they may encounter in their everyday lives, and nurture their mathematical literacy.

I-S problems, which are contextualized and having various solutions or no solution at all, are more interesting and meaningful to learners, whereas well-structured problems, which are commonly encountered in school mathematics, have a single solutions, include all the elements required to solve the problems and have structured goals. (Chi & Glaser, 1985; Hong, 1999; Jonassen, 1997; Kitchner, 1983).

In the past, I-S problems followed the same process for problem solving as well-structured problems. In contrast, I-S problems are now considered to be differentiated from convergent problems because they are contextualized and relevant to everyday life (Ge & Land, 2003; Jonassen, 1997). According to analyses of the I-S problem solving process (Ge & Land, 2003; Hong, 1999; Jonassen, 1997), I-S problems generally include the steps for problem representation, solution creation & justification, and evaluation. As discussed above, because I-S problems are reflective of more complicated real-world situations and, unlike well-structured problems, have multiple solutions allowing various analyses of the problem situations, the justification and evaluation procedures are more segmented during problem solving. Such problems can be undertaken in several phases, such as analyzing and understanding the problem, creating various solutions, decision-making & implementation, justifying and evaluation. They could be solved in various ways depending on how the learners analyze the problem situation, what kind of plan they decide based on the results of analysis, and how they utilize their individual knowledge.

Kim, Sharp, and Thompson (1998) carried out the method of I-S problem solving with multimedia based on constructivism in pre-service elementary teacher education program. The results suggest that the experiment influenced the pre-service teachers' decisions to plan more constructivist-based teaching strategies and develop their problem-planning ability by integrating story-based I-S problem solving. It is thought that the constructivist teaching and method based on situational contexts by utilizing the multimedia unlike the traditional mathematics teaching and learning had a positive impact on problem solving of pre-service teachers.

In addition, Kim, Min, and Kim (2011) have conducted the research to analyze the perception of elementary school teachers about situation-contextual problem. Two hundred elementary school teachers were surveyed and most of them showed that problem such as I-S problem would be useful and applicable to improve students' problem solving.

As both evaluation of the appropriateness and justification take place at the same time in the process of planning and implementation, learners must understand the problem situations and review them, which requires meta-cognition (Garofalo & Lester, 1985). The regulation of metacognition, including evaluation, monitoring and planning, plays an important role in I-S problem solving (Cho & Kim, 2006). Analyzing the behavioral features of each phase in I-S problem solving can serve as a starting point for nurturing the problem solving abilities of learners.

Motivation

PISA conducted a survey by dividing motivation into two groups: intrinsic and instrumental. Intrinsic motivation referred to a learner's enjoyment of mathematics, whereas instrumental motivation indicated the utility of mathematics, which motivated the learner to study it. According to the results of the 2012 PISA, Korea showed the highest levels in terms of the variable explaining the level of mathematical achievement, whereas the intrinsic motivation index of Korean students was below the OECD average (Song et al., 2013). Since intrinsic motivation is considered to have an exceptionally great impact on mathematic achievement, it is a critical element of mathematics education. Therefore, there is a strong need in Korea to pay more attention to intrinsic motivation, since we live in a society where too much of the educational focus is placed on college entrance examinations.

Generally, motivation is a kind of internal status that triggers certain actions, while presenting and maintaining the direction of the actions. From the cognitive view, intrinsic motivation is very important for learners, because humans, by nature, are creatures filled with curiosity who constantly seek out information and solutions relevant to themselves (Woolfolk, 1998). Motivation plays a big role in encouraging students to become interested and display the curiosity needed to support increased learning about a particular subject, such as mathematics. Therefore, mathematics education should put emphasis not only on teaching mathematical procedural skills and problem solving strategies, but also on allowing students to gain more confidence in doing mathematics. This could help students gain intrinsic motivation from a long-term perspective (Braheir, 2011).

Schunk (1991) also acknowledged motivation as one of the factors prompting students to select tasks by themselves and constantly work hard to solve problems in difficult situations. Motivation is the power that makes students start and keep going in their studies to achieve their learning goals. Therefore, it is important for teachers to understand students from a motivational point of view to illicit a constant effort to learn mathematics.

In Korea, Bong et al. (2012) developed the Student Motivation in the Learning Environment Scales (SMILES) in order to accurately measure the psychological

process of students and the related learning processes. In addition, SMILES was also designed to identify the unique features and tendencies of Korean students, which could be found only in Korean culture. SMILES contains a total of nine learning strategy scales. The motivational dispositions consist of both challenge and safety orientations. Challenge orientation is where learners display inclination of approaching potential compensation, risks, or sensory stimuli, while having positive attitudes and willingness to confront new tasks. Safety orientation, on the other hand, is indicative of learners who have the tendency to avoid potential punishment, uncertainty, failure, or harm, while generally having negative opinions and taking safer options rather than challenging tasks.

Among the various aspects, this study focused on the motivational dispositions related to the features of I-S problems and problem solving, including cognitive engagement and academic self-regulation. Academic self-regulation measures the cyclical process in which students set up a plan, review and implement it in order to achieve their study goals. As discussed above, I-S problem solving requires learners to have the ability to independently review, modify and complement their own problem solving processes. Therefore, in terms of I-S problem solving, the whole cyclical process of planning, reviewing, implementing and self-reflecting could have a great influence.

Bobis, Anderson, Martin, & Way (2011) suggested the utilization of real, relevant and open-ended tasks as a strategy to increase motivation in mathematics classrooms. By borrowing sources from students' lives either inside or outside of school, the real and relevant tasks were found to be likely to encourage the development of mathematical ideas through interaction between those who have interest in the task and those who don't, which can trigger motivation to actively participate in mathematical activities. Kim (2008) reported significant differences in the process of I-S problem solving depending on whether the given task was closely related to the students' lives. As the relevance increases, learners are more likely to interpret problems for their own benefits and interests, which can lead to motivation because of familiarity with the task.

RESEARCH METHODS

Participants

Twenty pre-service elementary teachers from two classes participated in this study. Eight of them were students of the Department of Elementary Education, College of Education at a Seoul-based university, who were enrolled in the elective subject of a mathematics-related seminar class opened for freshmen during the first semester of 2013. The remaining 12 juniors were enrolled in Elementary School Mathematics Basic Principles as a mandatory subject class.

Through use of the pre-test results on motivation, the participants were divided into two groups. Depending on their motivation scores, the participants were divided into the Highly-motivated Group or Low-motivated Group, after which they were once again segmented into a total of 6 subgroups containing 3-4 people (see Table 1).

By including different groups of pre-service teachers, this study aimed to explain

Table 1. Groups of participants

Year of school	Highly-motivated	Low-motivated	Total
Freshmen	Group A (N=4)	Group D (N=4)	8
Junior	Group B (N=3)	Group E (N=3)	6
	Group C (N=3)	Group F (N=3)	6
Total	10	10	20

the common characteristics that could be found in those with the different levels of motivation during the I-S problem solving process.

Procedure

This study was carried out in the following order: pre-test, I-S problem solving, and post-test (see Figure 1).

The pre-test was first carried out to measure the motivation of participants. The items in the motivation questionnaire were based on the SMILES by Bong et al. (2012), including motivational dispositions, cognitive engagement and academic self-regulation.

The I-S problem solving process followed a five phase model called A-B-C-D-E (Analyze/Browse/Create/Decision-Making/Evaluate) (see Table 2) for 75 min. In this study, six groups of two classes were monitored by audio-recording, and each group had an observer, totaling 6 people.

To help the participants understand the contextualized, complicated and I-S problem situations, they were applied in the order of individual activities, small group activities and plenary activities (see Figure 2). First, the participants were asked to analyze and explore a problem situation and then come up with a possible solution during the individual activity. Based on this, problem solving was then
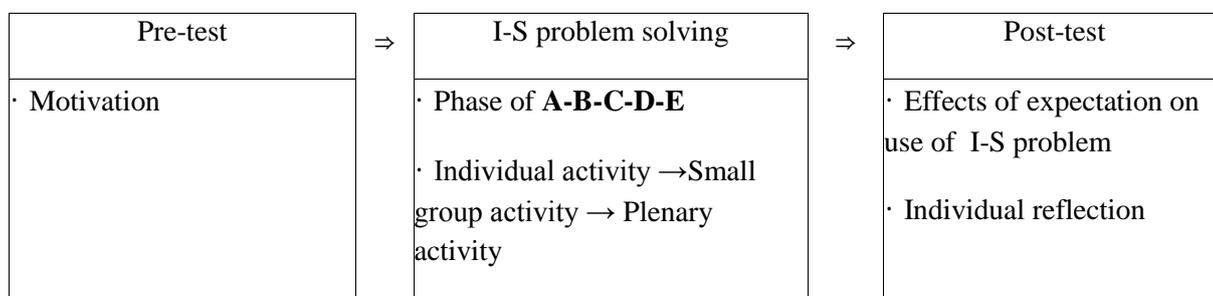
Pre-test		I-S problem solving		Post-test
· Motivation	⇒	· Phase of **A-B-C-D-E** · Individual activity →Small group activity → Plenary activity	⇒	· Effects of expectation on use of I-S problem · Individual reflection

Figure 1. Research process of this study

Table 2. A-B-C-D-E model of ill-structured problem solving

| Phase	Checklists
Analyze	Did they review the problem from an analytical perspective? Did they understand the given program? Can they redefine the problem they have to solve with their own terms, figures or tables? (Diversity of problem representation)
Browse	Did they identify the necessary conditions? Did they identify the mathematical content they need to know to solve the given problem? Did they collect information or data necessary to solve the given problem?
Create	Can they formulate solutions that can satisfy a multitude of conditions? Can they come up with various solutions to the given problem?
Decision-Making	Can they justify the most appropriate solution to the problem from a mathematical perspective?
Evaluate	Can they evaluate other participants' sets of solutions to compare them to their own problem solving process and do they reflect on the differences? Can they identify a better idea out from other groups' solutions and can they modify and complement their own solutions?
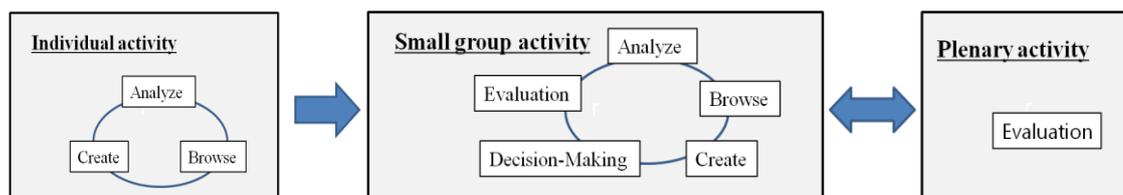
Figure 2. Procedure of I-S problem solving

conducted in small groups. It is important for members to share their ideas within groups, because the I-S problems could be understood in various ways depending on how the individuals understood the problem situation. After finishing the small-group problem solving, the participants shared the problem solving process and the results obtained with the other groups during the plenary activity session.

Finally, in the post-test, a simple survey was conducted on the expected benefits when utilizing I-S problems in an elementary school mathematics classroom. In addition, the participants were asked to write down their individual reflections on the I-S problem solving activities.

Ill-structured problem

The I-S problem used herein was entitled, "We got a new children's book café!" This was a contextualized task, which included large numbers and mixed calculations, and was designed for fourth graders of elementary school (see Kim, Heo, Cho, & Park, 2012). Participants were given the problem, in which they were asked to figure out whether it would be cost-efficient for Migyeong (name) to subscribe to a membership of the newly opened book café. In this process, the participants were supposed to consider two aspects, weekly visit plan and cost.

The weekly visit plan could vary depending on which day of the week the participants would choose to go to book café based on the weekly schedule of the problem situation. It determined how many days the participants could go to the book café for the given 3 months. The cost would then be determined based on the weekly visit plan and one-day entrance fees. To estimate the most reasonable membership fees for the book café, they needed to calculate and compare the costs of using the book café as a member or as a non-member.

To solve this problem needs algebraic reasoning, as it required the problem solvers to distinguish variable elements from invariable elements in the problem leading to setting up a related formula to understand the given problem.

Data collection and analysis

To monitor the problem solving process of each group, video cameras and voice recorders were used to film and record the group activities. In addition, the activity sheets that the test participants used during the process, as well as the field notes of observers, were collected. An observer was assigned to each group. The observers were mostly students currently enrolled in masters or doctorate degree courses for Elementary School Mathematics Education or Special Education for Mathematics Talented Students. The observers solved the study task prior to the observation by themselves, were fully informed of the guidelines and precautions for writing field notes, and discussed the matters concerned.

The problem solving activity process was designed to follow the A-B-C-D-E phase, as presented in Table 2. The A-B-C-D-E phase includes Analyze, Browse, Create, Decision-Making and Evaluation stages, which were developed from Dewey's 6 stages (Identifying a problematic situation; Defining the problem; Devising a plan; Carrying out the plan; Undergoing or living through the consequences; and Evaluating) and Polya's 4 stages (Understanding the problem; Devising a plan; Executing the plan; and Evaluating or reflecting on the complicated process), and were later re-designed for application to I-S problem solving (see Kim & Park, 2014). Activity sheets for each phase of the I-S problem solving contained the detailed questions that the participants need to consider in order to solve the problem.

The phases of I-S problem solving were used as an analysis unit in order to determine what kinds of characteristics were revealed in the I-S problem solving process. However, according to the first round of analysis results, the Analyze phase could not be clearly distinguished from the Browse phase, and the two phases took

Table 3. Criteria of analysis in I-S problem solving

Phase	Criteria of analysis
Analyze & Browse	• Analyze the problem based on the given information. • Browse and understand the problem situation through analysis of the problem.
Create	• Create a variety of plans for problem solving.
Decision-Making	• Make a decision for the most reasonable option among the suggested solutions after having implemented the various problem solutions.
Evaluate	• Evaluate the problem solving process and the final solution.

place almost at the same time. The final analysis results showed that the I-S problem solving processes were actually divided into the four stages - Analyze & Browse, Create, Decision-Making and Evaluation - which were monitored to identify what characteristics could be revealed from problem solving analysis perspectives.

RESULTS

Group problem solving proceeded based on the individual problem solving, starting with the sharing of each member's ideas within the group. The individual problem solving was considered as the preparation and Analyze & Browse phase of the I-S problem solving of the groups. For this study, in-depth analysis was conducted on the problem solving process depending on the levels of motivation of the groups.

Ill-structured problem solving of groups with different levels of motivation

To solve the problem, the participants first had to decide how many days Migyeong would go to the book café in reference to her weekly schedule and calculate the total number of available days for the given 3 months excluding days in which the book café was closed, using the calendar included in the problem. By utilizing information about the membership subscription fees and daily entrance fees as suggested in the problem situation, they then needed to compare the costs of using the book café as a member or as a non-member, and then come up with the best option.

Highly-motivated group

The highly-motivated group included Groups A, B and C, all of which tried to find the days of the week on which Migyeong could go to the book café, understanding and analyzing the information given in the weekly schedule. After discussing which days of the week it would be possible for Migyeong to go to the book café, they calculated the total number of available days for 3 months and compared the cost differences depending on the number of days per week selected (for example, three times per week, twice per week, or once per week). Some groups even suggested convergent results by integrating all possible cases to solve this problem, while others suggested all possible results in order. In addition, some groups suggested proper membership fees in consideration of both Migyeong's perspective and the book café's. The diagrams for the highly-motivated group's problem solving process can be summarized as in Figure 3.

The problem solving process of Group A will be elaborated on as the most representative example. As shown in Figures 4 and 5, to compare the respective costs of being a member and a non-member, Group A analyzed the weekly schedule
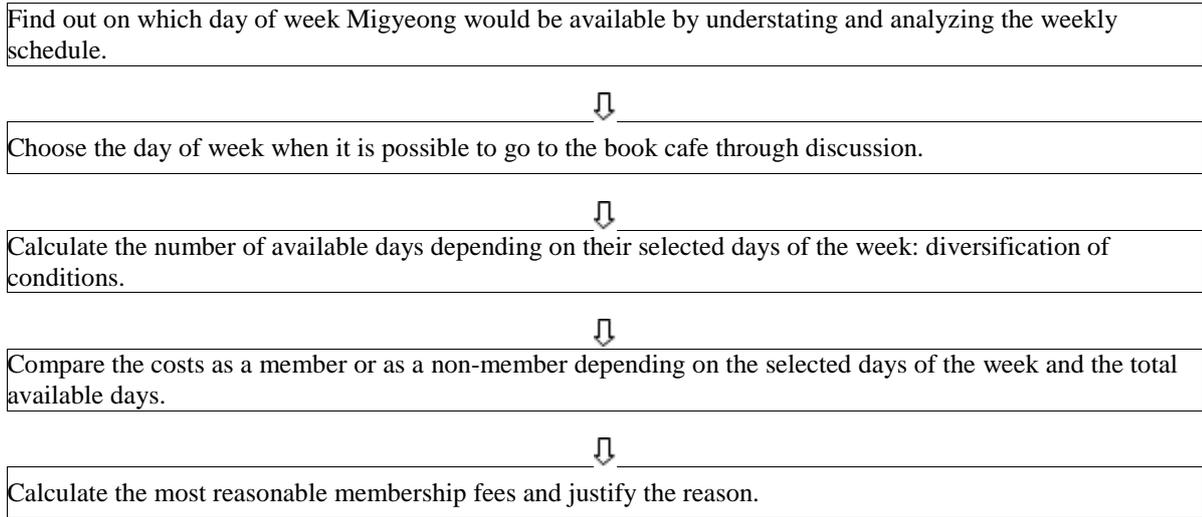
Find out on which day of week Migyeong would be available by understating and analyzing the weekly schedule.

⇩

Choose the day of week when it is possible to go to the book cafe through discussion.

⇩

Calculate the number of available days depending on their selected days of the week: diversification of conditions.

⇩

Compare the costs as a member or as a non-member depending on the selected days of the week and the total available days.

⇩

Calculate the most reasonable membership fees and justify the reason.

Figure 3. Problem solving process from highly-motivated group

Migyeong thinks that to subscribe to the membership of a book cafe would be cost-efficient.
To compare the total of daily entrance fees for 3 months :

< as a non-member>   < as a member>
1200 won * x days > (y won * x days) + 5000won

x days : the total number of days for going to the book cafe
for 3 months

y won : one-day entrance fee for members

Figure 4. The example 1 of problem solving from Group A (Translated in English)

Depending on the weekly visit plan and usage frequency for 3 months:
 a) To go to the book cafe for 2.5 days per week :
   33 days * 1200won > 5000won + 33days* x
    $x < 1048.5$
 b) To go to the book cafe for 3 days per week:
   35 days * 1200won > 5000won + 35days* x
    $x < 1057.1$
 c) To go to the book cafe for 4 days per week:
   48 days * 1200won > 5000won + 48days*x
   $x < 1095.8$

x : one-day entrance fee for members

Figure 5. he example 2 of problem solving from Group A (Translated in English)

and calculated how many days per week it would be possible to go to the book café, and then compared the membership fee with the total of the daily entrance fees according to different plans. According to the analysis of Group A's problem solving process, the openness in the problem solving process, in which different judgments and interpretations were possible and diverse manipulations were allowed, was clearly shown. This meant that the way in which Group A solved the problem reflected that the I-S problem had greater problem space than a well-structured problem, with diverse possible solutions.

Low-motivated group.

The low-motivated groups included Groups D, E and F, all of which analyzed the information given on the weekly schedule. These groups used two different methods. One was to calculate the number of the days of the week when Migyeong had enough time after school (Strategy 1), and the other was to calculate the total number of days if Migyeong were to go to the book cafe everyday regardless of the weekly schedule (Strategy 2). The diagrams for the problem solving processes of these groups were expressed simply in Figure 6.

As shown in Figure 6, these groups tried to compare the cost differences between members and non-members. However, they didn't recognize that the number of available days may have varied depending on how they analyzed the weekly schedule during the I-S problem solving. Their problem solving strategy went on without carrying out an in-depth analysis of the weekly schedule, and without providing a clear enough interpretation of how it was decided how many days of the week it would be possible to go to the book café. This meant that their problem solving did not reflect the openness and complexity of the I-S problem solving process, in which the problem situation could be interpreted from various perspectives due to similarity to the real world, wherein diverse judgments and interpretations would have been possible and various manipulations could have been allowed.
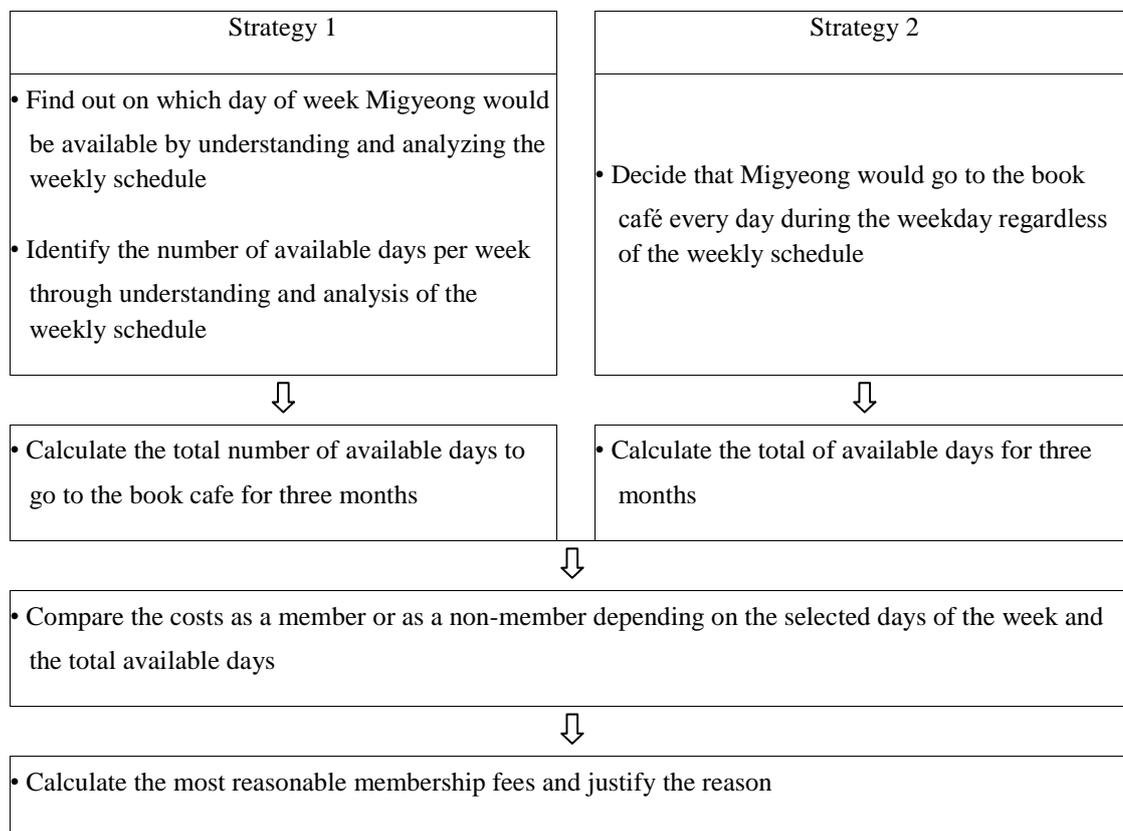
Strategy 1	Strategy 2
• Find out on which day of week Migyeong would be available by understanding and analyzing the weekly schedule • Identify the number of available days per week through understanding and analysis of the weekly schedule	• Decide that Migyeong would go to the book café every day during the weekday regardless of the weekly schedule

⇩ ⇩

• Calculate the total number of available days to go to the book cafe for three months	• Calculate the total of available days for three months

⇩

• Compare the costs as a member or as a non-member depending on the selected days of the week and the total available days

⇩

• Calculate the most reasonable membership fees and justify the reason

Figure 6. I-S problem solving process from low-motivated group

Phase-specific ill-structured problem solving characteristics of groups with different levels of motivation

After analyzing the process by dividing it into phases, it was found that the Analyze and Browse phases took place at the same time. Therefore, it was decided to that the process should be analyzed with division into four phases: Analyze & Browse, Create, Decision-Making and Evaluation.

Highly-motivated group

A partial analysis on each phase of the I-S problem solving process was conducted based on the overall problem solving process suggested in Figure 3. The common characteristics found in each phase for the highly-motivated groups were as follows.

In the Analyze & Browse phase, the participants were very curious about the problem situation and tried to analyze it in depth. When they were trying to find out which days of the week Migyeong was available to go the book café through understanding and analyzing the weekly schedule provided with the problem situation, they tried to associate the problem situation with their own lives and explained the reasons by exemplifying situations they had experienced. With these methods, they could help their group members understand better, and were able to conduct an in-depth analysis on the problem.

In the Create phase, they tried to create various ideas based on the in-depth analysis. If necessary, they went back to the Analyze & Browse phase to carry out additional analyses on the problem situation to produce more ideas. They discussed to set up a book café visit plan by deciding which days of the week they thought would be good for Migyeong to go to the book café, and then calculated the number of available days over the three months. At that time, they tried to diversify the conditions for choosing the available days of the week. They checked the appropriateness of their strategy (their self-formulated strategy) to choose the available days of the week by undergoing a review on their process through linking the chosen days of the week to the matters discussed during the Analyze & Browse phase.

In the Decision-Making phase, the group members checked the appropriateness of their self-formulated strategy by themselves. The decision-making, based on these results, was conducted to select the best option. They then compared the costs of using the book café as a member and as a non-member during the available days of the week, which they had calculated on the basis of the book café visit plan. They then calculated the most reasonable membership fee and justified the reasons. At that time, review was continuously done to check the appropriateness of their ideas from the Create phase.

In the Evaluation phase, they justified the group's solution to the members of other groups by explaining the links between the Analyze & Browse, Create and Decision Making phases.The common characteristics that were observed in each phase of I-S problem solving of the highly-motivated groups were summarized in Figure 7.

The phase-specific characteristics of the I-S problem solving of the above-mentioned highly-motivated groups can be exemplified with the case of Group C.

In the Analyze & Browse phase, the members of Group C reviewed how they analyzed the problem situation (refer to <Extract 1>). While analyzing and understanding the weekly schedule given in the problem situation, the group members showed curiosity about the situation by exemplifying their own experiences of being a paid member in a fitness center (S3), and analyzing the problem situation from the view of general elementary school students (S2).

> S2: I thought it was realistic in the beginning. When children heard about the opening of a new book café, I thought they would all want to go. When I was trying to solve the problem on the condition that Migyeong could go on every day of the week, I thought it was too easy. Then I looked at the weekly schedule, and saw school finished at 4:30 on Tuesday. As I looked at the schedule more,
> (omitting)
> I didn't read to the end of the schedule, I thought it might be more or less the same. Then it occurred to me that children could easily get

Phase	Process of problem solving	Common characteristics
Analyze Browse	Find out on which day of week Migyeong would be available by understating and analyzing the weekly schedule	· Showed curiosity in the problem by relating to their experience · Analyzed the problem situation in depth
Create	Choose the day of week when it is possible to go to the book cafe through discussion ⇩ Calculate the number of available days depending on their selected days of the week: diversification of conditions	· Created various ideas based on the in-depth analysis · Went back to the Analyze & Browse phase · Checked the appropriateness of their strategy
Decision-Making	Compare the costs as a member or as a non-member depending on the selected days of the week and the total available days ⇩ Calculate the most reasonable membership fees and justify the reason	· Went back to the Create phase · Selected the best option based on continuous check of the appropriateness about their created ideas
Evaluation	• Share the process of problem solving and result with group	· Considered the relation among A &B, C and D phases

Figure 7. Common characteristic of problem solving in each phase from highly-motivated group

bored of going to the book café, and that not all of them wanted to go because children like to play more than they like to read. I thought that it was difficult to decide how many days they could and wanted to go to the book cafe. As I was dwelling on it, the time was up.

S3: I just thought that children would not go to a book cafe every day. I once subscribed to a membership at a fitness club. I went there almost every day for about a month, then I missed most of the days for the next two months. So, instead of thinking on the condition that she would go to the book café every day, we assumed that she would want to go whenever she had enough free time after school. <Extract 1>

In the Create phase, the members of group C created diverse ideas and did an in-depth analysis in order to better understand the problem situation by going back to the Analyze & Browse phase (refer to <Extract 2>). At the same time, further analysis was also conducted to review the appropriateness of the ideas about which days of the week to choose.

S1: Well, if we assume she could go three times a week, then she could go 10 times, 12 times and 12 times for each of the three months. Let's say she would go 10 times each month, but maybe she doesn't want to go as many as 10 times. In the book café, she can read books and enjoy

drinks. Even if she does not want to read a book, she might still want to enjoy a drink and she could drop by the book café to get one.
S2: Well, that might be true.
S1: When she happens to go by the bookstore and feels thirsty, she can drop by the book cafe and take out a drink, and the daily entrance fees only cost 1,200 won.
S2: Maybe after playing.
S1: Maybe she can drop by after finishing her violin lesson. Then, it is better to subscribe to the membership. However, she can't go every day. She wants to play sometimes, right?
S2: For the book cafe, selling drinks is more profitable. I guess the drink is still too expensive. Anyway, as I looked into the problem situation, we have to calculate the available days based on the condition that Migyeong is thinking about going to the book café for three months. This might indicate she really likes reading books and wants to go to the book café as often as possible. She could go there to read books or enjoy drinks. Besides, she can use the book café as a sort of meeting place with her friends. Then, let's try to calculate how many days she would want to go there. <Extract 2>

In the Decision-Making phase, the members of group C tried to choose the best option by continuously reviewing the execution results of their selected strategies. They also tried to simplify the problem situation and justify their decision-making process in order to review and evaluate the appropriateness of their chosen method by themselves.

In the Evaluation phase, Group C shared the process and procedure of their problem session with the members of other groups. They explained the premise with which they started solving the problem based on the problem situation, and the related analysis results. In addition, they also explained whether their chosen strategy reflected the aspects of losses and gains or not when they compared the costs for using the book café as a member or as a non-member. In addition, unlike the other groups who suggested calculating only the available days of the week and the costs depending on the frequency, Group C was characterized by trying to improve the results of their solutions, offering the most reasonable costs in consideration of a set of available days of the week and depending on the frequency, while also suggesting how often Migyeong would have to go to make the best use of her membership if she were a member. In the process of explaining the meaning of the problem situation and justifying the problem solving strategy, it was demonstrated that the A, B, C and D phases of I-S problem solving were related to each other. This was due to the much wider problem space of I-S problems in relation to well-structured problems. The universal characteristics of I-S problem solving, that various solutions are possible depending on how the problem situation is interpreted, was clearly shown in the problem solving process of Group C.

If taking into consideration the problem solving processes and the phase-specific characteristics of Group A, B and C, all of which belonged to the highly-motivated group, it can be seen that the A-B-C-D-E phases of I-S problem solving were not linked in a linear connection, but rather flexibly went back and forth among all phases as needed. In other words, how the participants analyzed and browsed the problem situation led to the creation of various solutions for that problem, which they continuously reviewed by linking the created solutions to the problem situation. This stimulated re-analysis of the problem situation. Through this process, the participants were able to create other ideas that they had not thought of before, thus leading to the Decision-Making procedure wherein they decided on the best option. Therefore, the review was continuously done during each of the A-B-C-D

phases of I-S problem solving, which, if necessary, could be mutually cyclically connected.

Low-motivated group.

A partial analysis was conducted based on the overall problem solving process suggested in Figure 6. The common characteristics in each phase for the low-motivated groups were as follows.

In the Analyze & Browse phase, the low-motivated groups displayed the tendency of superficially analyzing the information given in the problem situation. This can be interpreted to mean that the problem solvers did not have curiosity about the problem situation, and thus did not actively participate in the problem solving process. In addition, as they only analyzed the problem situation superficially, each group member could not clearly explain how they understood the problem situation. Consequently, as there was not much to discuss with each other, they quickly moved on to the Create phase.

In the Create phase, an idea for the solutions was created. However, they failed to diversify the conditions with the information given in the problem situation because of their superficial analysis and understanding of the problem situation. Since they were not able to diversify the problem solving plans, they ended up coming up with only one solution. As a result, they again quickly moved on to the Decision-Making phase of the problem solving plan and did not even have a chance to review the problem solving plan created or the analysis results of the given problem situation.

In the Decision-Making phase, they implemented the only solution they had come up with in the Create phase, and were inclined to think that it was the only possible solution.

In the Evaluation phase, they stopped at reporting their group's problem solving process in which they underwent the A-B-C-E phases as well as the subsequent results, rather than explaining and justifying the solution to the members of other groups.

The common characteristics that were observed in each phase of I-S problem solving among the low-motivated groups can be summed up in Figure 8. The phase-specific characteristics during each step of the I-S problem solving of the low-motivated groups can be explained by exemplifying the case of Group D.

It was monitored how the members of Group D analyzed the problem situation in the Analyze & Browse phase. When they analyzed the problem situation, instead of showing curiosity in the problem situation, linking it to their lives to allow a better understanding, or showing interest in other members' opinions, they simply stated their own opinions and failed to have an in-depth discussion with group members. They also failed to initiate an analytical discussion as to why they decided that Migyeong would to go the book café on Mondays, Thursdays and Saturdays, and stopped at superficially analyzing the situation (refer to <Extract 3>).

> S3: To make the best use of the membership, it is better to go to the book café as often as possible.
> S4: Do you think it would be waste of time if she only had a short period to spend at the book cafe because of the tight schedule?
> S2: In the case that Migyeong stayed at the book cafe for a long time from time to time, do you think you she need to go less often?
> S3: It is good to go to the book cafe as often as possible, but on Tuesdays and Wednesdays, school finishes at 4:30.
> S4: When do the after-school hours start and finish?
> S3: It is possible to go to the book café during the free time she has between appointments? <Extract 3>

As they failed to conduct an in-depth analysis on the problem situation in the Analyze & Browse phase, they narrowed the list of available days of the week to

Phase	Problem solving		Common characteristics
	Strategy 1	Strategy 2	
Analyze & Browse	• Find out on which day of week Migyeong would be available by understating and analyzing the weekly schedule	• Decide that Migyeong would go to the book café every day during the weekday regardless of the weekly schedule	· Superficially analyzed the problem situation · Quickly moved onto the Create phase
Create	• Calculate the total number of available days to go to the book cafe for three months	• Calculate the total of available days for three months	· Ended up coming up with only one solution · Quickly moved on to the Decision-Making phase
Decision-Making	• Compare the costs as a member or as a non-member depending on the total available days ⇩ • Calculate the most reasonable membership fees and justify the reason		· Implemented the only solution they came up with in the Create phase
Evaluation	• Share the process of problem solving and result with group		· Showed lack of explanations and justifying the solution

Figure 8. Common characteristics of problem solving in each phase from low-motivated group

Monday, Thursday and Saturday but failed to assort the combinations of available days of the week to come up with various solutions. Instead, they formulated a strategy on the condition that she could go to the book café on Monday, Thursday and Saturday. There were not many analysis results about the problem situation, and not enough discussion in the Create phase, where a problem solving plan was supposed to be created based on the analysis. They showed the tendency of quickly moving on to the Decision-Making phase.

In the Decision-Making phase, they implemented the problem solving plan they had created in the Create phase. They stopped to associate the plan to the information given in the problem situation to check if there were any errors in their process, but they failed to go back to the problem solving plans by going back to the previous phases and reanalyzing the information. In addition, they did not try to review the problem solving process they implemented, and did not show any interest in the other members' opinions, only showing the tendency of quickly finishing the problem solving phase.

In the Evaluation phase, when presenting to other group members about the process and results of their respective problem solving, they could not provide an appropriate explanation of the relationship between the meaning of the problem situation and their chosen solution. This can be interpreted as meaning that they failed to accept the processes in phases A-B-C-D as a meaningful experience. In

addition, as they superficially analyzed the problem situation, they stopped at reporting the calculation process they did during the problem solving process.

Taking into consideration the problem solving processes and phase-specific characteristics of Groups D, E and F, all of which belonged to the low-motivated groups, there was not much discussion among the group members. As underwent superficial analysis to understand the problem situation and came up with only one solution, they showed an inclination to quickly move on to the next phase of the I-S problem solving process, and consequently failed to implement each phase meaningfully.

DISCUSSION AND IMPLICATIONS

This study was based on the premise that I-S problems could be utilized to improve the field sites of mathematics education. In addition, to allow change of the current mathematics teaching and learning in order to boost students' creative problem solving ability, this study aimed to identify the phase-specific characteristics of the I-S problem solving process among groups with different levels of motivation.

Comparison of the phase-specific characteristics of the groups with different levels of motivation revealed the following. In the Analyze & Browse phase, whether or not students show interest in looking for a correlation between the problem situation and their own experiences will decide if they understood the problem situation superficially or thoroughly. Only when participants analyzed and understood the problem thoroughly in the Analyze & Browse phase, they could offer solutions based on a variety of ideas produced in the Create phase.

In addition, when the review process was carried out by recursively moving from the Create phase to the Analyze & Browse phase, it was possible to bring out various ideas for problem solving. In the Decision-Making process, the best option was selected by reviewing the created ideas. Participants were able to justify their own problem solving processes and results in the Evaluation phase only when they understood the relationship between the problem-solving phases: analysis of the problem, understanding how to plan a solution, and finding the best solution.

Furthermore, the highly-motivated groups actively participated during the discussion in each phase of I-S problem solving, so that each phase was carried out in a meaningful way. If the problem situation was thoroughly discussed through agreement between the group members, they could create various ideas and select the best solution by comparison. In order to ensure that agreement could be reached in this process, they had to find the close relations between the phases of I-S problem solving. In that case, a more advanced and holistic problem solving process could be realized.

In light of the abovementioned discussions, this study was carried out to identify the educational implications of I-S problem solving from the perspective of pre-service teacher education. If we first take into consideration the results from the phase-specific analysis of the I-S problem solving process, it seems that the level of problem analysis and understanding could decide the quality of the subsequent phases. Hong (1999) reported that it was critical to have an understanding of I-S problems in order to be able to solve them, because the elements of problem situation, which are needed to analyze in order to solve that problem, are ambiguously defined. Therefore, there is a strong need to recognize the necessity of developing problems based on a realistic situational context in pre-service teacher education, and to offer opportunities to mathematize I-S problems to further identify the mathematical potential from everyday math.

Second, this study on I-S problem solving was conducted by dividing the participants into subgroups according to the levels of motivation. Based on results, it

seems that sufficient discussion and agreement among group members was needed to ensure that each phase was conducted in a meaningful way. Problem solving often requires teamwork rather than individual exploration, and there have been efforts made in recent years to expand the scope of learning through collaboration at school, such as through project-based learning, inquiry-based learning and problem-based learning, in order to respond to these needs. In addition, problem-solving abilities are considered by the OECD as an important asset for future society. Consequently, PISA 2015 will introduce a "Collaborative Problem Solving", which evaluates the ability of individuals in collaborative situations. All in all, it seems that collaboration for discussion among subgroup members is an influential factor in I-S problem solving. Therefore, it is thought that we should not ignore the necessity for the formation of subgroups and collaborative problem solving through subgroup activities in pre-service teacher education.

Third, this study found remarkable differences in terms of I-S problem solving depending on the levels of motivation of the participants. In I-S problem solving, the different levels of motivation reminded us of the need to bridge the gap between those with or without high problem-solving abilities. As suggested in a study by Rowland (1992), which explained the reason for the differences between beginners and experts in terms of problem solving, and another study by Ge and Land (2003), which mentioned the utilization and effectiveness of question prompts which help learners to solve I-S problems, problem solving abilities can be improved with the help of teachers. Therefore, an educational program on methodological aspects must be included to help improve the problem solving ability of students, as well as their motivation, in pre-service teacher education. That is to say, that there is a need to provide more concrete information on how much a teacher should help students, and how to encourage them to actively participate in the problem solving process.

Finally, the study results by Auguste, Kihn, and Miller (2010) suggested that Korean teachers were human resources with high levels of achievement, but they have almost no experience in terms of I-S problem solving, which is characterized by authenticity, openness. Even in the self-reflection on I-S problem solving activities written by the pre-service teachers who participated, it was expressed that they felt at a loss when they first encountered the I-S problem; however, they gave very positive feedback on this new experience that they had never had the chance to experience before. It is noteworthy that the level of problem solving and the related experiences of pre-service teachers can have a significant influence on the problem solving ability of their learners. Providing an opportunity to experience I-S problems, as characterized by authenticity, complexity and openness, will be greatly appreciated not only by the students who have to address various problems in a complicated and rapidly changing society, but also by the pre-service teachers who will teach them in the future. Pre-service teachers need to experience the I-S problem solving process to ensure that mathematics education should help students better understand and solve the problems which would be encountered in the real world.

ACKNOWLEDGEMENTS

REFERENCES

Arcavi, A. (2002). The everyday and the academic in mathematics. In M. E. Brenner, & J. N. Moschkovich (Eds.), *Everyday and academic mathematics in the classroom* (pp. 12-29). Reston, VA: NCTM.

Auguste, B., Kihn, P., & Miller, M. (2010). *Closing the talent gap: Attracting and retaining top-third graduates to careers in teaching-An international and market research-based perspective.* New York, NY: McKinsey & Company.

Bobis, J., Anderson, J., Martin, A., & Way, J. (2011). A model for mathematics instruction to enhance student motivation and engagement. In D. J. Brahier & W. R. Speer (Eds.), *Motivation and disposition: pathways to learning mathematics* (pp. 31-42). Reston, VA: National Council of Teachers of Mathematics.

Bong, M. M., Kim, S. I., Johnmarshall, R., Lim, H. J., Lee, W., Jiang, Y. et al. (2012). *Student motivation in the learning environment scales*. Retrieved Feb 8, 2015, from Korea University, The Brain and Motivation Research Institute Web site: http://bmri.korea.ac.kr/korean/research/assessment_scales/list.html?id=assessment

Brahier, D. J. (2011). Introduction: motivation and disposition: the hidden curriculum. In D. J. Brahier & W. R. Speer (Eds.), *Motivation and disposition: pathways to learning mathematics* (pp. 1-8). Reston, VA: National Council of Teachers of Mathematics.

Chi, M. T. H., & Glaser, R. (1985). Problem solving ability. In R. J. Sternberg (Ed.), *Human abilities: an information processing approach*. New York, NY: W. H. Freeman.

Cho, K. L., & Kim, S. Y. (2006). The Effects of cognitive styles 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.

Dewey, J. (1933). *How we think: A restatement of reflective thinking to the educative process*. Boston: MA: Health & Co. Publishers.

Garofalo, J., & Lester, F. (1985). Metacognition, cognitive monitoring, and mathematical performance. *Journal for Research in Mathematics education, 16*(3), 163-176.

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.

Hong, N. S. (1999). *The relationship between well-structured and ill-structured problem solving in multimedia simulation* (Unpublished doctoral dissertation). The Pennsylvania State University, US.

Jonassen, D. H. (1997). Instructional design models for well-structured and ill-structured problem-solving learning outcomes. *Educational Technology Research & Development, 45*(1), pp. 65-94.

Kim, M. K., Heo, J. Y., Cho, M. K., & Park, Y. M. (2012). An analysis on the 4th graders' ill-structured problem solving and reasoning. *Journal of Korean Society Mathematics Education Series A: The Mathematical Education*, *51*(2), 95-114.

Kim, M. K., Heo, J. Y. & Park, E. J. (2014). Design, application and its educational implication of ill-structured problem solving in elementary mathematics education. *Journal of Elementary Mathematics in Korea*. *18*(2), 189-209.

Kim, M. K., Kim, H. W., Min, S. H., Park, E. J., Lee, J., Cho, M. K., et al. (2014). *Ill-structured problem and problem solving*. Seoul, Korea: Kyungmoonsa.

Kim, M. K., Lee, J., Hong, J. Y., & Kim, E. K. (2011). A study of 'Ill-Structured' status from mathematics problems in elementary school textbooks. *Journal of Learner-Centered Curriculum and Instruction, 11*(2), 1-21.

Kim, M. K., Min, S. H., & Kim, H. W. (2011). A study of the elementary teachers' perception about the situation-contextual problem in mathematics education. Journal of Korean Society Mathematics Education Series A: The Mathematical Education, *50*(2), 149-164.

Kim, M. K., & Park, E. J. (2014). Children's proportional reasoning on problem type of proportion according to ill-structured degree. *Journal of the Korean School Mathematics Society, 16*(4), 719-743.

Kim, M. K., Park, E. J., & Heo, J. Y. (2012). An analysis on mathematics textbook problems focusing on 'contextualization'. *Journal of the Korean School Mathematics Society, 15*(1), 1-25.

Kim, M. K., Sharp, J. M., & Thompson, A. D. (1998). Effects of integrating problem solving, interactive multimedia, and constructivism in teacher education. *Journal of Educational Computing Research, 19*(1), 83-108.

Kim, S. Y. (2008). The effects of awareness of problem type familiarity and problem relevance on ill-structured problem-solving process and achievement. *Journal of Educational Technology*, *24*(2), 105-128.

Kitchner, K. S. (1983). Cognition, metacognition, and epistemic cognition: a three-level model of cognitive processing. *Human Development, 26*, 222-232.

Moschkovich, J. N. (2002). An introduction to examining everyday and academic mathematical practices. In M. E. Brenner, & J. N. Moschkovich (Eds.), *Everyday and academic mathematics in the classroom* (pp. 1-11). Reston, VA: NCTM.

National Council of Teachers of Mathematics (1991). *Professional standards for teaching mathematics*. Reston, VA: NCTM.

Polya, G. (1981). *Mathematical discovery*. New York, NY: John Wiley & Sons.

Rowland, G. (1992). What do instructional designers actually do? An initial investigation of expert practice. *Performance Improvement Quarterly, 5*(2), 65-86.

Schunk D. H. (1991). Self-efficacy and academic motivation. *Educational Psychologist, 36*(3 & 4), 207-231.

Song, M. Y., Im, H. M., Choi, H. J., Park, H. Y., Seon, S. K. (2013). *OECD Programme for International Students Assessment: Analyzing PISA 2012 Results*. Korea Institute for Curriculum and Evaluation. RRE 2013-6-1.

Woolfolk, A. E. (1998). *Educational psychology* (7th ed.). Boston: Ally and Bacon.

❖ ❖ ❖