Development of Ill-Structured Problems for Elementary Learners to Learn by Computer-Based Modeling Tools

Ji Na Byun, Dai Young Kwon, and Won Gyu Lee

***Abstract*—Modeling is used as a learning method because learners can experience a conceptual change. These days, computers are used in modeling activity to perform the modeling process effectively and efficiently in classroom. Therefore, this study developed contents for mathematical modeling class using Spreadsheet and GSP, computer-based modeling tools instructors can easily experience. After development, we applied the contents to actual classwork, and measured the changes in students' attitudes toward mathematics and technology before and after the classwork. As a result of the application of the program, this work brought about the educational effects as follows: First, computer-based modeling activity increased one's self-esteem in using technology. Secondly, experiencing mathematical modeling with computers was instrumental in learning mathematics. Thirdly, computer modeling activity positively increased students' attitudes toward mathematics and technology.**

***Index Terms*—Computer modeling tools, ill-structured problem, spreadsheet, GSP.**

I. Introduction

Engineering modeling is a technique to find an optimized case through testing and simulation. Such modeling is used as a learning method as well. That is because learners can experience construction and change of conceptual understanding, or conceptual change, through modeling [1]. Jonassen, who studied constructivist learning environments, said that the modeling process of turning an implicit conceptual model into an explicit model helps learners leading conceptual change. These days, computers are used to perform the modeling process effectively and efficiently in classwork [2].

Computer-based modeling tools have the following strong points:

First, since computers process complicated and additional operations on behalf of learners, learners can focus on the core of the problem. Secondly, in the circumstance where multiple learners perform their own modeling process, instructors have difficulties in giving feedback to each one's model at the same time. Computers, however, help to provide feedback for each learner through simulation in the course of each learner's modeling. Therefore, learners can quickly understand where they are in the whole process of the modeling and where errors occur.

Based on the strong points, constant efforts to apply modeling activity to classwork have been made. However, studies about using the conventional modeling tools for learning either used software applications that teachers were not able to experience easily [3] or focused on higher learners [4], [5]. Therefore, this study developed contents for mathematical modeling class using Spreadsheet and GSP, computer-based modeling tools instructors can easily experience. After development, we applied the contents to actual classwork, and measured the changes in students' attitudes toward mathematics and technology before and after the classwork.

The paper is structured as follows. Section II reviews research on ill-structured problems and computer-based modeling tools. Section III introduces two ill-structured problems we developed. Section IV estimates the participants'' behavior changes and Section V concludes.

II. Background

A. Ill-Structured Problem

The problems whose all factors are described in detail are called a well-defined problem or a well-structured problem, whereas the problems whose at least one factor is not described in detail is referred to as an ill-defined problem or an ill-structured problem [6].

Although there is no clear boundary between a well-structured problem and an ill-structured problem, the ill-structured problem is less complicated and less clear than the well-structured problem in terms of the criteria to determine whether a goal is achieved, and it has no simple and definite rule in finding a solution [7].

An ill-structured problem appears from a specific context and gets situated. So it means a problem whose situational aspects are not materialized and whose description is neither clear nor well-defined [8]. In addition, the problem has multiple solutions or solution paths or has no solution [9], and it has unclear definition and uncertain goal status, and has no limiting condition.

As for the ill-structured problem that many researchers defined in various ways, Min-kyung Kim et al. defined it with authenticity, complexity, and openness [10]. Authenticity represents that mathematical tasks describing the daily life situation and the actual situation outside school is consistent with a problem [11]. In order for a problem to have authenticity, the problem should deal with the context of daily life and imitate the critical parts of the actual situation as much as one can reason them [12]. Complexity represents a) uncertainty of the concepts, principles, and rules required to solve a problem, or of their organization and b) inconsistent relationship between the concepts, principles and rules of the

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cases involved in a problem [13]. Openness presents something that allows students to make various interpretations of problem-solving and to justify their own interpretation [14].

According to the characteristics of the ill-structured problem, many researchers suggested the processes of solving an ill-structured problem, different from the processes of solving a well-structured problem. For an ill-structured problem solving model, Sinnott proposed the process including construction of a problem space, choice and creation of a solution, monitor/memory/non-cognitive factors, and use of think-aloud protocol [15], Jonassen proposed an ill-structured problem solving model which includes a) presentation of problem space and contextual constraint, b) verification of alternative views, standpoints and perspectives, c) creation of possible problem-solving methods, d) evaluation of feasibility of alternative solution methods through construction of disputes and expression of personal belief, e) monitoring of problem space and choice of a solution, f) execution of a chosen solution and monitoring, and g) the process of applying the chosen solution[13].

Ge and Land, also defined ill-structured problem as four processes like problem representation, developing solutions, developing justification, and monitoring and evaluation [16].

B. *Computer-Based Modeling Tools as Cognitive Tools*

Jonassen proposed some computer-based modeling tools as a cognitive tool supporting learner's cognitive process [1].

The computer-based modeling tools support learners interacting with knowledge on CLEs. [17]. There are some examples such as the Semantic Organization Tools showing what the learner do and what the learner learn, the Dynamic Modeling Tools helping learners to represent dynamically the relationship between idea, the Information Interpretation Tools helping learners to show the project that they are conducting, and the Knowledge Construction Tools helping learners to collect important information for solving problem [18].

TABLE I: JONASSEN'S MINDTOOLS

Category	Tools
Semantic Organization	Databases Semantic Networking
Dynamic Modeling Tools	Spreadsheets Expert Systems Systems Modeling Tools Micro-worlds
Information Interpretation Tools	Visualization Tools
Knowledge Construction Tools	Hypermedia
Conversation Tools	Chatting

III. DEVELOPMENT OF ILL-STRUCTURED PROBLEMS

We have developed two Ill-structured problems for elementary learners to experience mathematical modeling using computer-based modeling tools.

Above all, we selected two computer-based modeling tools spreadsheet and GSP those are generally used in classworks. Spreadsheet belongs to Dynamic Modeling Tools and GSP belong to Information Interpretation Tools according to the Table I. Next, we determined the type of solution with considering the characters of the tools.

The first problem is for spreadsheet that useful to solve 'what if' problems on diverse conditions. This problem has a numerical basis and the learners have to show the calculating result after finding optimized case in this problem.

The second problem is for GSP that show the outputs using diagrams. In this problem the learners have to solve as drawing a situation that satisfied the problem's conditions.

With those conditions of solutions, the problems are developed based on authenticity, complexity and openness.

The table below shows that S cell phone carrier's calling plan diagram.

Attribute	Plan1	Plan2	Plan3	Plan4
Monthly fee(₩)	12,000	35,000	55,000	9,000
Call rate(₩/sec)	18/10	18/10	16/10	25/10
Free(min)	x	250	450	30

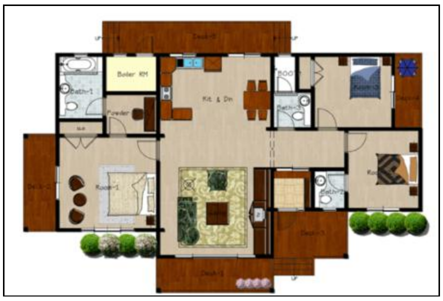
Mr. K is going to buy a new cell phone. Mr. K normally calls about 470 minutes a month and use for one year. If he use one year, which is the most efficient?

Fig. 1. Ill-structured problem for spreadsheet.

The Fig. 1 is the problem 1 for spreadsheet. This problem is reflected authenticity by presenting a cell phone plan selection situation that learners can access in the real-world situation. And because of the four kinds of rate situations(Plan) and the various attributes such as monthly fee and free of charge, it is satisfied the complexity. In addition, it satisfied the openness due to including a variety of strategies to use the tools despite the solution what the problem demand is fixed.

The problem 2 for GSP is Fig. 2.

A Police station is going to set some CCTV for Ms. Jang to prevent from Mr. Min.



1) However, only three CCTV can be installed and the specification is as follows. When the CCTVs are installed beyond the fence in the picture below, where are the appropriate locations to record all around the house for 24 hours?

CCTV1: 7m to shoot and can be rotated 70˚
CCTV2: 8m to shoot and can be rotated 70˚
CCTV3: 9m to shoot and can be rotated 100˚

2) Consider another case. There are many CCTVs that can shoot to 8m and can be rotated 90˚. How many CCTVs are needed to record all around the house?

Fig. 2. The Ill-structured problem for GSP.

In this problem CCTV installation was offered as a situation to be satisfied the authenticity. However considering the probability that most learners had never been suffered the case in the real-world, a situation of a drama that was famous among the learners was offered. Moreover it sufficient the complexity as offering the complex shape of the house and different specifications of CCTVs, and the openness is also satisfied because the learners can use a variety of methods and give varying results.

IV. Applying the Contents

A. Participants and Period

24 elementary-school students participated in the study. Participants came from K University Math & Informatics Institute and participated for nine hours in this program. Below Table II is the participants' general information.

TABLE II: Participants' General Information

		Year11	Year12	Year13	Total
Gender	Male	2	8	5	15
	Female	3	4	2	9
Total		5	12	7	24

B. Impact of Learners' Attitude to Mathematics and Technology

We estimated Participants' attitude about mathematics and technology to evaluate the problems what had developed in the study. For this estimation we used the mathematics and technology attitudes scale (MTAS) developed by Pierce *et al.* (2007) [19] and performed pre- and post. The instrument consists of 20 items. A Likert-type scoring format is used for each of the subscales: behavioral engagement [BE], mathematics confidence [MC], confidence with technology [TC], attitude to learning mathematics with technology (especially computers in this study) [MT], affective engagement [AE]. Students are asked to indicate the extent of their agreement with each statement, on a five-point scale from strongly agree to strongly disagree (scored from 5 to 1).

Pierce *et al.* (2007) defined the subscales of the MTAS scale as follows:

1) Behavioral engagement [BE]: how students behave in learning mathematics.
2) Confidence with technology [TC]: technology confidence as evidenced by students who feel self-assured in operating computers, believe they can master computer procedures required of them, are more sure of their answers when supported by a computer, and in cases of mistakes in computer work are confident of resolving the problem themselves. Confidence with technology was also considered as a construct relating to life outside as well as inside the classroom.
3) Mathematics confidence [MC]: students' perception of their ability to attain good results and their assurance that they can handle difficulties in mathematics.
4) Affective engagement [AE]: how students feel about mathematics.
5) Attitude to learning mathematics with technology [MT]: students indicating high computer and mathematics interaction believe that computer enhance mathematical learning by the provision of many examples, find note-making helpful to augment screen based information, undertake a review soon after each computer session, and find computer helpful in linking algebraic and geometric ideas.

According to pre-and post- test results, there are significant differences on 8 items. The one is behavioral engagement, the two are confidence with technology, and other one is mathematics confidence. Especially all subscales of attitude to learning mathematics with technology have significant difference between pre-and post- test.

TABLE III: Pre-and Post- MTAS Result by Items

Division	Pre	Post	*t*	Significance Probability
BE1	4.14	4.19	-.439	.666
BE2	4.04	4.23	-1.073	.296
BE3	4.00	4.19	-1.000	.329
BE4	3.95	4.38	-3.236	.004*
TC1	4.23	4.52	-2.828	.010*
TC2	4.23	4.38	-1.000	.329
TC3	3.61	4.09	-2.500	.021*
TC4	4.80	4.57	1.746	.096
MC1	3.95	3.90	.252	.803
MC2	3.71	4.00	-2.335	.030*
MC3	3.57	4.00	-1.910	.071
MC4	3.90	4.09	-.847	.407
AE1	4.23	4.23	.000	1.000
AE2	4.09	4.28	-1.164	.258
AE3	3.95	4.04	-.357	.724
AE4	4.23	4.04	1.451	.162
MT1	4.00	4.43	-2.905	.009*
MT2	3.62	4.24	-2.210	.039*
MT3	4.10	4.48	-2.359	.029*
MT4	4.05	4.48	-3.873	.001*

$*p<.05$

We also tried to analyze depending on the class what the participants study in such as mathematics (n=11) and informatics (n=13). However there is no significant difference between mathematics and information.

V. Conclusion

This work tried to develop educational contents for computer-based modeling activity and to apply the contents to mathematics course. As a result of the application of the program, this work brought about the educational effects as follows:

First, computer-based modeling activity increased one's self-esteem in using technology. Before and after the application of the program, there was no significant difference in one's self esteem of using the devices and software applications not experienced in class (TC2, TC4), whereas, as shown in TC1 and TC3, one's self-esteem of using computers generally increased.

Secondly, by modeling activities based on computer with the ill-structured problems we had developed learners recognized that computers help to learn mathematics (MT1~MT4). Therefore, if learners experience various modeling activities as well as mathematical modeling activity based on computers, it is expected that they will be able to recognize that computer modeling tools are helpful in solving various problems in the real world and to utilize them.

Thirdly, computer modeling activity positively increased students' attitudes toward mathematics and technology. Such attitudes showed no difference in both informatics class and mathematics class. In other words, both students who constantly experienced learning of information devices and students who constantly experienced in-depth learning about mathematics changed their awareness in the same level.

In order for learners to effectively use computer-based modeling tools in building a model, it is necessary to use the modeling tools in various situations. In so doing, learners can understand the strong points and features of computer-based modeling tools, choose a proper modeling tool as they face a problem to be solved, and effectively and efficiently solve the problem. Therefore, to induce more effective modeling learning with the use of computer-based modeling tools, it is necessary to keep suggesting and developing diversified and proper problems that learners can experience.

APPENDIX

TABLE IV: FACTOR STRUCTURE OF MTAS SCALE

Code	Questions
BE1	I concentrate hard in math.
BE2	I try to answer questions the teacher asks.
BE3	If I make mistakes, I work until I have corrected them.
BE4	If I can′t do a problem, I keep trying different ideas.
TC1	I am good at using computers.
TC2	I am good at using things like VCRs, DVDs, MP3s and mobile phones.
TC3	I can fix a lot of computer problems.
TC4	I can master any computer programs needed for school.
MC1	I have a mathematical mind.
MC2	I can get good results in math.
MC3	I know I can handle difficulties in math.
MC4	I am confident with math.
AE1	I am interested to learn new things in math.
AE2	In math you get rewards for your efforts.
AE3	Learning math is enjoyable.
AE4	I get a sense of satisfaction when I solve math problems.
MT1	I like using graphics calculators and computers in math.
MT2	Using graphics calculators and computers in math is worth the extra effort .
MT3	Math is more interesting when using computers.
MT4	Computers help me learn math better.

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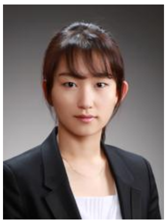

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