Key factors for Successful Integration of Technology into the Classroom: Textbooks and Teachers

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Abstract *The purpose of this paper is to investigate the causes of why technology has not been integrated into mathematics teaching by teachers. We considered two aspects to examine the causes; Korean mathematics textbooks as teaching materials implementing technology, and teachers' concern on using technology and their levels of its use. First, we analyzed the role of technology in mathematics learning and teaching, especially concentrated on 7 kinds of Korean Secondary school mathematics; Middle School Mathematics 1, 2, 3, High School Mathematics, Mathematics Ⅰ, Ⅱ, Pre-Calculus & Pre-Statistics, Integration & Statistics and Geometry & Vector. Secondly, we surveyed 231 Korean secondary mathematics teachers' concerns about integrating technology into their mathematics education and the teachers' level of its use in the mathematics classroom. We found that mathematics teachers need more proper information and support to integrate technology into teaching mathematics. Additionally, this paper suggests that educational researchers or administrators help teachers move toward more practical use of technology without emotional or physical barriers in mathematics classroom.*

1. Introduction

Over the last few decades the rapid development of technology has greatly influenced a wide range of fields throughout society. It also brought forth many changes to mathematics education. Mathematics educators have studied how to use technology effectively for learning and teaching mathematics and have tried to integrate technology into mathematics classroom. These studies showed that technology can lead improvement of mathematics learning and teaching in many aspects. Technology can foster a student to conjecture, justify and generalize mathematical contents by doing fast and accurate computation and analysis of various representations ([21], [23]). Considering the educational advantages, many curricular documents in the whole world now emphasize integrating technology with mathematics education. Especially, [19] mentioned that technology is an essential tool for learning mathematics in the 21st century. In the case of Korean curriculum, technology was first mentioned in the Sixth Curriculum ([16], [17]). Furthermore, in the 2007 Revised Curriculum, the application scope of technology use was extended to be included in assessment contents, as well as learning and teaching mathematics ([16], [17], [18]).

According to [13] and [6], the integration of technology into mathematic education, especially at secondary levels, had not achieved all that many researchers and educators have expected. There are many constraints or barriers including educational environments. However, the crucial factor in integrating technology into mathematics education is the role of mathematics teachers ([4], [14], [11]). A teacher has the right not only to choose methods to teach mathematics but also to implement the teaching methods in the classroom. Therefore, technology will never be integrated into mathematics education in practice unless the teacher makes use of technology in his or her classroom.

The purpose of this study is to investigate why technology has not been integrated into mathematics teaching by Korean teachers. We considered two aspects to examine the causes; Korean mathematics textbooks as teaching materials implementing technology and teachers' concern about using technology. This is because it is Korean mathematics textbooks that have implemented Korean mathematics curriculum in the classrooms, exerting a strong influence on the mathematics education sites. Additionally, Korean mathematics teachers are highly dependent on their textbooks to teach mathematics and students learn mathematics using the textbooks. We also considered teachers' attitude to use technology in mathematics classroom, especially focused on the concerns about using technology from among attitude.

Research Questions
The following questions are addressed in this research:

(1) What is the role of technology in Korean secondary mathematics textbooks?
(2) What pattern of concern do teachers express about technology integration in the instruction?
(3) What is teachers' stage of concern according to their level of using technology?

Significance of the Study
This study attempts to draw pedagogical implications in integrating technology into mathematics learning and teaching in an effective way by teacher. The results of this study help to figure out what the teachers need support to use technology in teaching mathematics. This study will contribute to the body of research that develops support teachers who use technology in their instructions.

2. Literature Review

The Role of Technology in Mathematics Learning and Teaching
[2]'s framework involved exploring, conjecturing, verifying, and generalizing as four key components of the role of technology in learning and teaching mathematics. Of the four components, the last three are fundamental processes of mathematical thinking, and the exploring and conjecturing processes are perceived to be important for developing technology-based mathematics lessons. They interpreted exploring, conjecturing, verifying, and generalizing as follows.

Table 2.1: The role of Technology in mathematics learning and teaching

Classification	Description of students' activity
Exploring	· Students inquire into a given task and then conduct their own investigation of the task based on instructions. · The instructions may suggest a particular heuristic to aid students' investigation rather than directly informing them what to do.
Conjecturing	· Students make an inference or a judgment about a given task based on their intuition or evidence from an exploration, which may still be inconclusive.
Verifying	· Students substantiate the truth of their conjecture by showing their reasons.
Generalizing	· Once students have finished exploring given task, as well as making and verifying conjectures, teachers can encourage students to extend the given task to a new problem situation. In other words, the given task becomes a specific case of the new problem situation. · The whole process of detecting and articulating the common characteristic from some cases is known as generalizing.

Additionally, Figure 2.1 provides a visual representation of the four components that make up the framework of [2]. It has a hierarchical structure with learning taking place in phases and culminating with the generalizing process. This upward progression implies the increasing degree of complexity of the tasks to be performed by students.

In [26]'s study, the authors noted that the role of technology in mathematics education required careful distinctions between two different kinds of mathematical activity: technical and conceptual (p.1170). Technical activity is concerned with tasks of mechanical or procedural performance, whereas conceptual activity is concerned with tasks of inquiry, articulation, and justification. Examples of technical mathematical activity include geometric construction and measurement, numerical computation, algebraic manipulation, solving equations, displaying, collecting, and sorting etc. Examples of conceptual mathematical activity consists of finding and describing patterns (inductive reasoning), defining, conjecturing, generalizing, abstracting, connecting representations, predicting, testing, proving, and refuting.

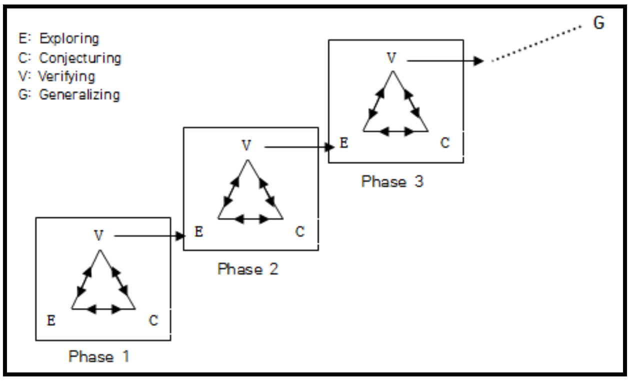


Figure2.1 visual representation of the four components

Korean mathematics curriculum

Korean school mathematics education includes two sorts of curriculum: National Common Basic Curriculum (NCBC) and Elective-Centered Curriculum (ECC). The former means that all Korean students should take the same mathematics subjects till the first grade high school, the latter means that students can choose which subjects to learn corresponding to their majors. Mathematics subjects in NCBC include Middle School Mathematics 1, 2, 3 and High School Mathematics, and the subjects in ECC consist of Mathematics Ⅰ, Mathematics Ⅱ, Pre-Calculus & Pre-Statistics, Integration &Statistics and Geometry & Vector.

The Stages of Concern

The Concern-Based Adoption Model (CBAM) was developed to provide "change facilitators with diagnostic tools" ([9]) to help each individual such as teacher adopt an educational innovation. In particular, [11] noted that the purpose of the CBAM was "to ease the problems diagnosing group and individual needs during the innovation adoption process". The model consisted of three diagnostic tools, such as the Innovation Configurations (IC), the Stages of Concern (SoC) and the Levels of Use (LoU). The SoC could be used to describe the concerns individuals had as they progress through the innovation process. As shown in the Table 2.2, the SoC consisted of 7 types of stages depending on in degree of individual's concern grasped through the Stages of Concern Questionnaire (SoCQ).

Table 2.2: The Stages of Concern on Integrating Technology into Mathematics Classroom

Stage		Description
0	Awareness	· Individual has little concern and involvement with using technology in the classrooms.
1	Informational	· Individual has general awareness of using technology and interest in learning more about how to integrate technology into the classrooms.
2	Personal	· Individual is uncertain about the demands of using technology and role in utilizing technology in the classrooms.

3	Management	· Individual's attention is focused on the processes and tasks of using technology and the best use of information and resources.
4	Consequence	· Individual focuses on impact of technology on their students.
5	Collaboration	· Individuals focus is on coordinating and cooperation with others regarding use of technology in the classrooms.
6	Refocusing	· Individuals focus on the exploration of more universal benefit from the use of technology

The Levels of Use

The LoU in the CBAM considered the behavioral aspect of change. CBAM authors suggested there were eight types of LoU in sequence from Nonuse to Renewal. The LoU described each individual's current implementation state of technology (See Table 2.3). The LoU could be assessed based on personal or group interview, and observation or questionnaire.

Table 2.3: The Levels of Technology-Use in Mathematics Classroom

Level		Description
0	Nonuse	· No action is being taken with respect to the use of technology in mathematics classroom.
Ⅰ	Orientation	· The teacher is seeking out information about the use of technology in mathematics classroom.
Ⅱ	Preparation	· The teacher is preparing to use the use of technology in mathematics classroom for the first time.
Ⅲ	Mechanical Use	· The teacher is using the use of technology in mathematics classroom in through a poorly coordinated manner and is making teacher-oriented changes.
ⅣA	Routine	· The teacher is making few or no changes and has an established pattern of use.
ⅣB	Refinement	· The teacher changes the use of technology in mathematics classroom to suit his or her needs.
Ⅴ	Integration	· The teacher is making deliberate efforts to coordinate with other teachers in using technology in mathematics classroom.
Ⅵ	Renewal	· The teacher is seeking more effective alternatives to the established the use of technology in mathematics classroom.

3. Methods

3.1. The Role of Technology in Korean secondary mathematics textbooks

Textbooks included in Analysis

The textbooks included in this analysis were 7 kinds of Korean Secondary school mathematics; Middle School Mathematics 1, 2, 3, High School Mathematics, Mathematics Ⅰ, Ⅱ, Pre-Calculus & Pre-Statistics, Integration & Statistics and Geometry & Vector. We examined as many kinds of Korean secondary mathematics textbooks approved by Ministry of Education as we could collect. As a result, we looked through 13 types of Middle School Mathematics 1, 17 types of Middle School Mathematics 2, and 13 types of Middle School Mathematics 3 in this study. In addition, 18 types of High School Mathematics, 11 types of Mathematics Ⅰ and Geometry & Vector, 10 types of MathematicsⅡand Integration & Statistics, and 12 types of textbooks of Pre-Calculus & Pre-Statistics in order to analyze the role of technology in learning and teaching mathematics. All of the textbooks in the study were based on 2007 revised mathematics curriculum except for Mathematics 1, which was based on 2009 revised curriculum. Presently, Korean secondary students have made use of textbooks with accordance with the curriculum at each level. See Table 3.1 for the total number of activities analyzed in each textbook.

Table 3.1: The total number of activities analyzed in each textbook

Textbooks	Number of activities analyzed
Middle School Mathematics 1	69
Middle School Mathematics 2	29
Middle School Mathematics 3	26
High School Mathematics	70
Mathematics Ⅰ	14
Mathematics Ⅱ	22
Pre-Calculus & Pre-Statistics	43
Integration & Statistics	25
Geometry & Vector	19

Instruments in Analysis

We modified results of [2] and [26] in order to construct our own framework which analyzes the role of technology in this study. Observing all examples of using technology presented in Korean mathematics textbooks, we found it necessary to divide the roles of technology into two categories according to the types of activity: technical and conceptual. Then we subdivided the categories. We considered whether examples presented in the textbooks are drill-and-practice (DP) or just for demonstration (DE). Then, we identified how the components of E-C-V triangle are connected to each other. Finally, we constructed the framework which analyzes the role of technology such as Table 3.2.

Table 3.2: Framework of the role of technology

	Role	Description
Technical	DP	· Students perform a given task by modeling example presented earlier or just compute numbers and mathematical expressions by using technology. · (e.g.) Solve the equation using given computer program.
	DE	· Textbook presents examples of using technology. However, a teacher may use the examples just for demonstration and students are not allowed any opportunities of being involved in activity.
Conceptual	E	· Students merely perform a given task by using technology according to instructions, and they are not allowed opportunities to come up with mathematical ideas or to identify a mathematical concept for themselves. · (e.g.) Find the equation of tangent line to the circle $x^2 + y^2 = 25$ at the point $(3, 4)$ by using computer program.
	E-C	· After students perform a given task by using technology according to instructions, they conjecture a mathematical concept based on their intuition or exploration. However, they are not allowed opportunities to verify their conjecture. · (e.g.) Draw two straight lines $y = -2x + 3$ and $2x+y+5=0$, and think about the relation of position between them.
	E-V	· After students perform a given task by using technology according to instructions, they directly verify a mathematical concept visually through exploration without process of conjecturing the concept. · (e.g.) Draw a parallelogram and its diagonals, and then mark the length of the diagonals. By dragging a vertex of the parallelogram, you can examine and verify the property that two diagonals of a parallelogram bisect the other despite of changing position and size of the parallelogram.

E-C-V	· After students perform a given task by using technology according to instructions, they conjecture a mathematical concept based on their intuition or exploration, and verify the conjecture. · (e.g.) Draw similar figures by using computer program and explore their properties. You can identify property and shape of the similar figures by changing ratio of similarity. Especially, you can conjecture relationship between ratio of similarity and ratio of the perimeter or ratio of the area because they are automatically calculated. Let's examine the properties of similar figures.
E-V-C	· After students perform a given task by using technology according to instructions, they directly verify a mathematical concept visually through exploration, and conjecture the relations. · (e.g.) Draw various graphs of functions, and then shrink or enlarge around a specific point through compute program. By the observation, you can verify some properties on each point on the graph. Let's discuss about your findings and conjecture the meaning of a differential coefficient.
E-V-G	· After E-V activity, students extend the given task to a new problem situation or articulate more general cases from the given task. · (e.g.) Construct a triangle, compute the sum of all the internal angles of the triangle, and then verify the sum is 180 degrees by changing shape of the triangle. By using computer program, draw various polygons, and compute the sum of all the internal angles of the polygons.
E-C -V-G	· After E-C-V activity, students extend the given task to a new problem situation or articulate more general cases from the given task. · (e.g.) Draw a pentagon, measure the size of all the external angles of the pentagon, and then find the sum of the angles. By moving the vertex of the pentagon, observe the sum of all external angles of a pentagon. By using computer program, find the sum of the external angles of various polygons.

In categorization of strands, NCBC in Korean school mathematics consists of five content domains, such as Numbers & Operations, Variables & Expressions, Functions, Probability & Statistics and Geometry. In terms of ECC, there are more diverse mathematics domains like Limit, Calculus, Matrix and Vector, including the five content domains. Therefore we found it necessary to re-categorize them into four types of content domains – Algebra, Analysis, Geometry and Probability & Statistics – for the framework in this paper. Details are tabled as follows.

Table 3.3: Framework of Categorization of Strands

Grade / Strand	Junior	Senior					
		Mathematics	Mathematics I	Mathematics II	Pre-Calculus & Pre-Statistics	Integration & Statistics	Geometry & Vector
Algebra	Numbers Operations Variables Expressions	Numbers Operations Variables Expressions	Numbers Operations Variables Expressions	Variables Expressions			Linear-transformation Vector
Analysis	Functions	Functions	Functions Sequences Limit	Limit Functions Differential	Differential Integral Functions Limit	Differential Integral Functions	Functions
Geometry	Geometry	Geometry		Geometry			Geometry
Probability Statistics	Probability Statistics	Probability Statistics			Probability Statistics	Probability Statistics	Probability Statistics

Data Analysis

In the study, we examined most kinds of Korean mathematics textbooks published in order to analyze the role of technology in teaching and learning mathematics according to the two frameworks (Table 3.2, Table 3.3). The analysis was basically a quantitative design with frequency analysis. To get a better understanding the data, we also elaborated on typical activities with each role of technology.

3.2. Korean Mathematics Teachers' Concern and Use of Technology

Sample included in Analysis

The sample of this study was taken from Korean mathematics teachers at secondary levels. Among 16 cities and provincial secondary schools, we collected data from each 16 junior and senior secondary schools. The total 231 participants were involved in the study, comprised of 70 (30.3%) taught in junior secondary schools and 161 (69.7%) taught in senior secondary schools. Of the total 231 participants involved in this survey, 82 (35.5%) were male teachers and 149 (64.5%) were females. In terms of participants' teaching experiences, 127 (55%) were less than 10 years, 55 (23.8%) were between 10 and 20, and 49 (21.2%) were more than 20 years.

Instruments in Analysis

The Stages of Concern

To investigate Korean secondary mathematics teachers' concern on integrating technology into mathematics classroom, we modified and utilized SoCQ with the purpose of this study. The teachers were asked to complete SoCQ which consisted of 35 statements expressing a level of concern about using technology in mathematics classrooms. Participants marked an 8-point Likert-type scale indicating the degree to which each concern was in concordance with their current states or opinions about technology in mathematics education. SoCQ was modified and developed by two times pilot tests. The sample of the first test answered the items on SoCQ and provided feedback with their expert opinion since they had either master's degree-level or doctoral-level training on mathematics education. The participants of the second test answered the modified items and we attempted to identify their comprehension of the questionnaire through individual interview. According to the tests, the internal reliability using Cronbach's α coefficient was 0.924 on the average of the eight stages scales. The validity of the questionnaire was assessed using judgments of interview and experts' opinion.

The Levels of Use

In the case of teachers' current levels of technology, the data were collected from questionnaire, including self-rating of the ability to integrate technology in their present teaching mathematics. Participants filled out the survey to describe the current state of using technology in mathematics classroom. In this study, we developed a questionnaire to examine the LoU of technology in mathematics classroom. The questionnaire was based on [15] and modified through two pilot tests in the same way as the SoCQ which had been compared with both the results of questionnaire and individuals' interview.

Data Analysis

The Stages of Concern

The teachers completed SoCQ and scores had a range of 0-35 for each SoC. A raw score for each stage was calculated by adding the five items that were included at the stage and converted into percentile scores. Data collected by the questionnaire were analyzed in two ways, such as 'The First-and Second-highest Stages Score Interpretation' and 'The Profile Interpretation'. The former could explain general issues of teachers' concern on using technology through frequency analysis, while the latter could interpret trends and patterns for SoC of the total group and each subgroup depending on LoU by descriptive statistics analysis. Additionally, the data were also analyzed to identify Korean teachers' features of SoC by averaging raw scores of each item at Stage 0.

The Levels of Use

We integrated three types LoU including Refinement, Integration and Renewal into Transformation, which re-categorize them into 6 kinds of levels of technology use. The data were analyzed against

LoU categories through frequency analysis and identified relationships between LoU subgroups and SoC profiles using descriptive statistics analysis. Finally, a one-way ANOVA was run to examine whether there were any differences in terms of LoU based on teachers' experience of learning or training with technology. A one-way ANOVA was chosen because the dependent variables, teachers' levels (Level 0-5), were known to be present over six LoU, and one effect (experience) was being used as independent variables.

4. Results

4.1. The Role of Technology in Korean secondary mathematics textbooks

Korean Junior Secondary Mathematics Textbooks

The junior secondary textbooks in the study had 124 activities which consisted of 69, 29 and 26 examples each textbook. According to the analysis, technology in Korean junior secondary textbooks was mainly used as conceptual role than a technical one (See Figure4.1). The conceptual role of technology made up almost 63.6 % of the total 124 activities, but 'E' and 'E-V' accounted for about 73.4 % of the total conceptual activities. According to the data of the junior secondary textbooks, the activities in Korean junior secondary mathematics lacked examples using technology as a conceptual role including conjecturing, verifying and generalizing.

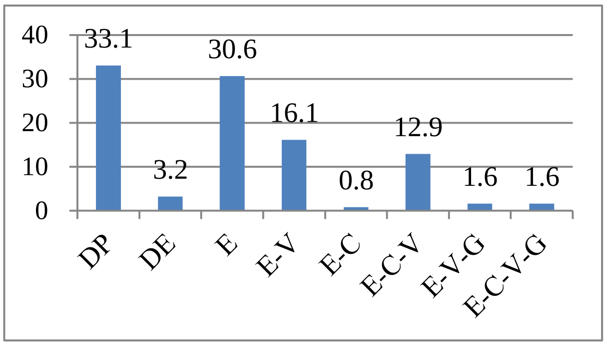


Figure 4.1 the role of technology in Korean junior secondary mathematics textbooks

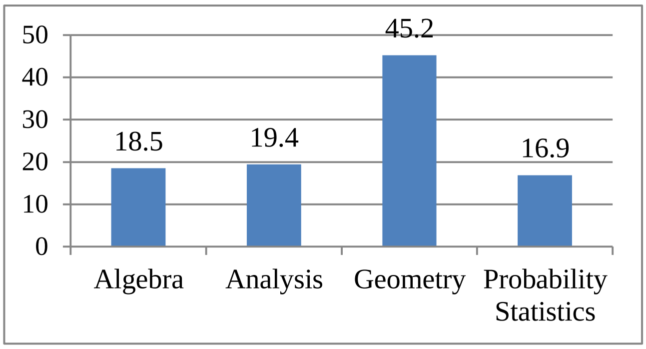


Figure 4.2 Distribution of activities with technology according to strands

As we analyzed below geometry took up the largest number of activities in the junior secondary mathematics textbooks. Geometry activities mostly made use of technology as a conceptual role more often than a technical one. As the examples above indicate, the key advantage of using technology in mathematics education is visualization of mathematical concepts not in a mind but in a computer screen. This is the reason why almost half of the activities were dealing with geometry.

The two figures, Figure 4.3 and Figure 4.4 below show the different roles of technology in the same mathematical strand, such as 'DP' and 'E' respectively. In Figure 4.3, students are simply required to enter the expression into the input window according to directions. In other words, students are required to make use of technology passively through instructions – guidance by a teacher or given materials – during the process of their problem solving. Students are instructed to merely draw graphs of various functions using these kinds of technology, which can be considered quite easy and simple. What this passive role of students in these activities mean is it is possible that the activities did not give students enough opportunities to come up with ideas to solve the problem on their own or display their problem solving. Therefore the example below as categorized as the 'DP' role of technology.

① Enter '$2x$' into the input window. ② Enter '$\frac{2}{x}$' into the input window.

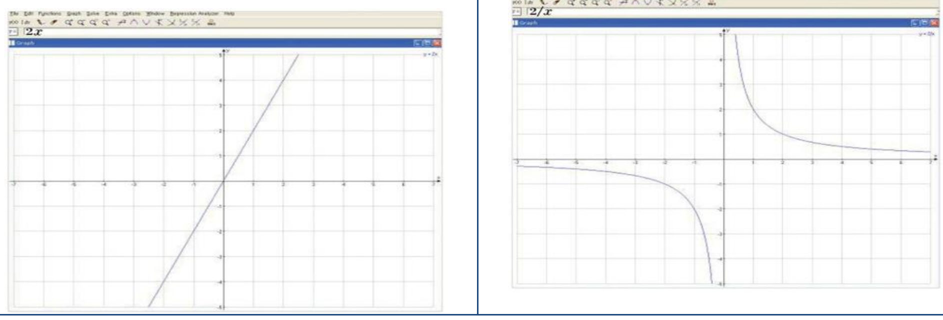


Figure 4.3 examples of 'DP' role of technology in Functions

Figure 4.4 shows an example of 'E' in the unit of functions. This activity is aimed at identifying features of the functions such as $y = ax\ (a \neq 0)$ and $y = \frac{a}{x}\ (a \neq 0, x \neq 0)$. Through drawing various graphs of functions which display these forms on a screen, students can understand the important features of the functions easily. Specifically, students can figure out some features of the functions through the activities and may find that the graphs are all laid on the first and third quadrants of the coordinates when $a > 0$, and conversely on the second and fourth quadrants when $a < 0$. In addition, students will be able to grasp that all graphs of $y = ax\ (a \neq 0)$ pass through zero, and the more the absolute value of a are high, the more the graph gets near to y-axis. Also, in the graphs of $y = \frac{a}{x}\ (a \neq 0, x \neq 0)$, the higher the absolute value of a is, the further the graph is from zero. Thus the example was classified 'E' because the use of technology helps students to visualize the mathematical concepts and leads them to understand what they are learning.

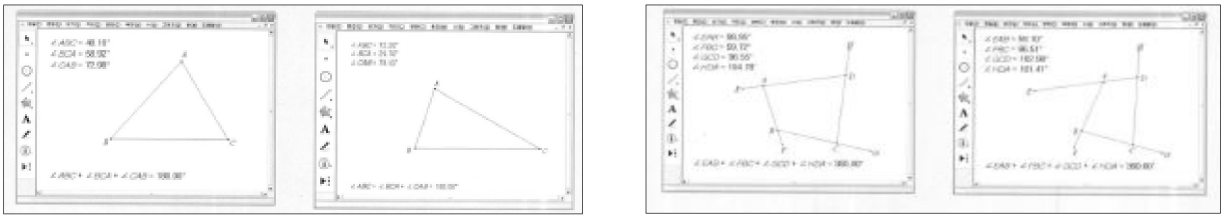
The graphs of $y = ax, a > 0$ The graphs of $y = \frac{a}{x}, a < 0$

Figure 4.4 an example of 'E' role of technology in Functions

The examples including 'Generalizing' are made up of two sorts of role of technology, such as 'E-V-G' and 'E-C-V-G'. The most distinctive feature of the examples is whether or not students have an opportunity to conjecture through their explorations using technology. In the case of 'E-V-G' Figure 4.5, students construct a triangle, compute the sum of all the internal angles of the triangle, and then verify whether the sum is 180 degrees by changing shape of the triangle. After that, they construct a quadrilateral, and do it the same way as they did in the activity of triangle. Students follow the directions given by a teacher or materials during the activity. In other words, the teacher or given materials instruct students specifically in the property they have to find or verify in the given figures. Following 'E-V', students draw various polygons and compute the sum of all the internal and external angles of the polygons by using computer program.

① Find the sum of all the internal angles of triangle

② Find the sum of all the external angles of quadrilateral



③ Find the sum of all internal and external angles of the polygons by using computer program

Figure 4.5 an example of 'E-V-G' role of technology

Korean Senior Secondary Mathematics Textbooks

In Korean senior secondary textbooks, the number of exercises with technology is 193. The activities consisted of 70, 14, 22, 43, 25 and 19 examples of the use of technology in the textbooks each subject, such as Mathematics, Mathematics Ⅰ, Mathematics Ⅱ, Pre-Calculus & Pre-Statistics, Integration & Statistics and Geometry & Vector. According to the study, the number of the activities such as 'DP' and 'DE' made up 59.7 % of the examples at the senior secondary level. It means that technology mainly plays a technical role in activities of Korean senior secondary mathematics textbooks. Moreover, the percent of technical examples is larger than that at the junior level by 23.4%. The data showed that the activities in Korean senior secondary mathematics textbooks lack examples with technology as a conceptual role, such as exploring, conjecturing, verifying and generalizing.

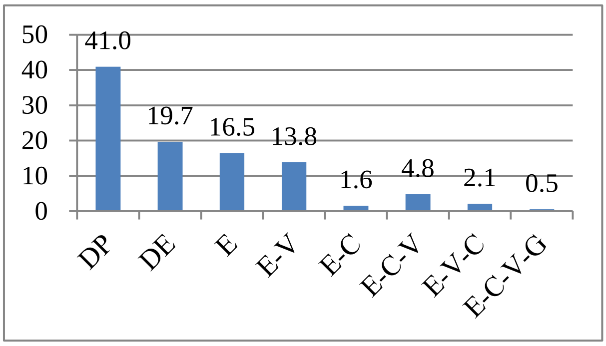


Figure 4.6 the role of technology in Korean senior secondary mathematics textbooks

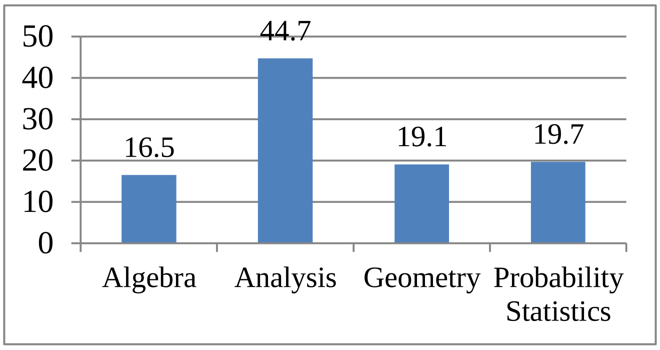


Figure 4.7 Distribution of activities with technology according to strands

In the case of Korean senior secondary mathematics textbooks, there was an obvious difference between the activities in senior textbooks and those in junior textbooks. While the examples of junior secondary mathematics textbooks were mainly based on geometric contents, about half of the activities at the high level include Analysis among the mathematical domains. The mathematical strand of the activities evenly consisted of functions, limit and calculus while technology in the activities was evenly composed of 'DP' or 'DE'.

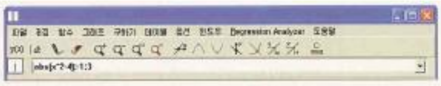
The examples of activities containing the technical role of technology in the senior textbooks consisted of solving equations according to teacher's directions or instructions of programs. It also consisted of finding values of data, and others such as standard deviation and variance, and computing definite integrals.

In Figure 4.8, for example, a student enters a mathematical formula in the input window and then the program immediately shows the area of the curve as a calculator does. The example in Figure 4.9 means that the concept of definite integral is explained by displaying areas of the rectangles and the concept of limit in the program. Figure 4.9 was categorized into 'DE' unlike Figure 4.8 which was suggested as an example of 'DP'. This is because the former showed that a student would make use of the technology as a calculator in finding the values, and they were just focused on the technical role of technology without exploring the concept of definite integral. On the other hand, the latter did not include any kind of students' activities in the activity with technology directly. The teacher would use the example to explain about the concept of definite integral through the demonstration for the whole class. For the reasons, we categorized the examples as 'DP' and 'DE' respectively.

Find the area of $y = x^2 - 4$ (surrended by $x - axis, x = -1, x = 3$) with the program.

Step1: Run the program, click ∫dx

Step2: Input abs(x^2−4);−1;3 into the window.



Step3: Press the enter key, and then you can find the answer.

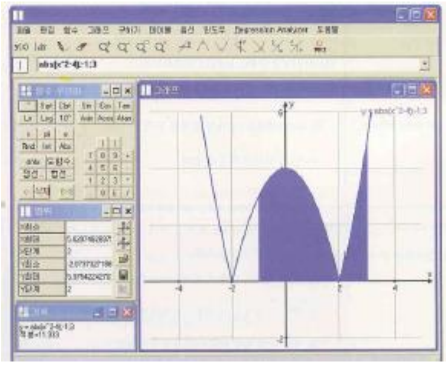
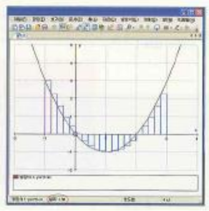
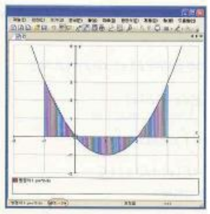


Figure 4.8 an example of 'DP'

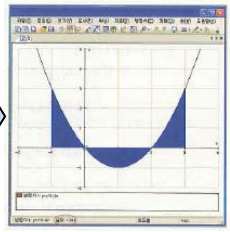
Let's find approximate of $\int_{-1}^{3}|x^2 - 2x|dx$ using the computer program.



The number of rectangles = 20 → 1.36



The number of rectangles = 100 → 1.334



The number of rectangles = 1000 → 1.333

The approximate value of the integral is approaching the true value depending on the number of rectangles.

Figure 4.9 an example of 'DE'

Additionally, there were a few activities of 'E-C-V' in the senior secondary textbooks. In the Figure 4.10, for example, students draw the graph of '$y = sin\,x$' by entering the expression into the input window in the program. While changing a point of contact of the graph, they may examine how the tangent line is changed and visualize the derivative. Then they can draw the derivative of '$y = sin\,x$' exactly by using the function 'drawing the graph of a derivative' of the software used, and verify that the derivative is '$y = cos\,x$' by dynamically examining the change of the tangent line. Actually, the fact that the derivative of '$y = sin\,x$' is the function of cosine is one of the most challenging issues for students to understand. All Mathematics Ⅱ textbooks explained the derivative of trigonometric functions algebraically by using various properties of trigonometric functions and limit. That is, when the increment of y on the increment of x, i.e. 'Δx', is marked with 'Δy'.

$$\Delta y = sin(x + \Delta x) - sin\,x = 2\,cos\left(x + \frac{\Delta x}{2}\right) sin\left(\frac{\Delta x}{2}\right)$$

$$\frac{dy}{dx} = \lim_{\Delta x \to 0} \frac{\Delta y}{\Delta x} = \lim_{\Delta x \to 0} \frac{2\,cos\left(x + \frac{\Delta x}{2}\right) sin\left(\frac{\Delta x}{2}\right)}{\Delta x}$$

$$= \lim_{\Delta x \to 0} cos\left(x + \frac{\Delta x}{2}\right) \cdot \lim_{\Delta x \to 0} \frac{sin\left(\frac{\Delta x}{2}\right)}{\frac{\Delta x}{2}} = cos\, x \cdot 1 = cos\, x$$

However, by allowing students to experience the processes like Figure 4.10, they can be provided visualization of seemingly abstract mathematical ideas and actively learn. These activities should be more widely used to encourage students to actively learn mathematics concepts, because they could conjecture and verify the ideas through their own exploration.

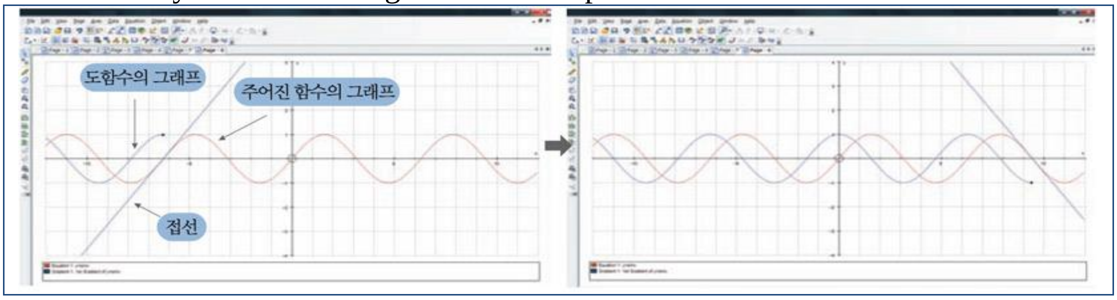
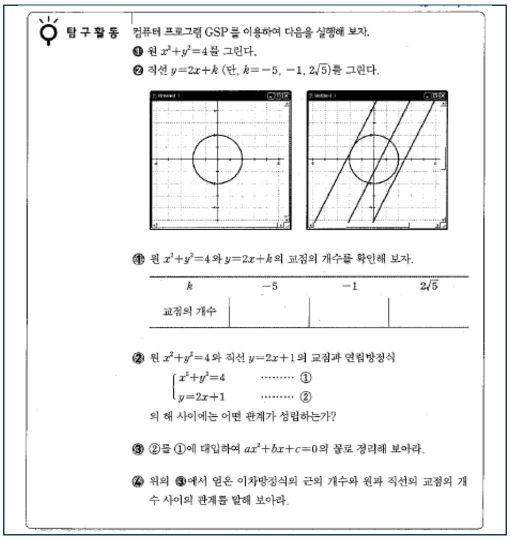


Figure 4.10 an example of 'E-C-V' role of technology

The number of the tasks in which students could try to solve problems through conjecturing based on exploring was larger than the junior secondary activities. However, it does not mean that the activities would give students enough and various chances to reflect on their problem solving. It should be noted that all of the activities with technology at the senior secondary levels included only one example for 'generalizing' or 'extension to new-complex situation' despite the importance of students' ability to generalize mathematical contents. Only one example of 'E-C-V-G' was founded including 'generalizing' at the senior levels (See Figure 4.11).



탐구활동 컴퓨터 프로그램 GSP를 이용하여 다음을 실행해 보자.

❶ 원 $x^2+y^2=4$를 그린다.

❷ 직선 $y=2x+k$ (단, $k=-5,\ -1,\ 2\sqrt{5}$)를 그린다.

❶ 원 $x^2+y^2=4$와 $y=2x+k$의 교점의 개수를 확인해 보자.

k	-5	-1	$2\sqrt{5}$
교점의 개수			

❷ 원 $x^2+y^2=4$와 직선 $y=2x+1$의 교점과 연립방정식

$$\begin{cases} x^2+y^2=4 & \cdots\cdots\cdots ① \\ y=2x+1 & \cdots\cdots\cdots ② \end{cases}$$

의 해 사이에는 어떤 관계가 성립하는가?

❸ ②를 ①에 대입하여 $ax^2+bx+c=0$의 꼴로 정리해 보아라.

❹ 위의 ❸에서 얻은 이차방정식의 근의 개수와 원과 직선의 교점의 개수 사이의 관계를 말해 보아라.

Figure 4.11 an example of 'E-C-V-G' role of technology

In the activity, students draw a circle and three lines with technology and find the intersections between the circle and the each line. They will fill the table with the number of intersections between them according to each case. Then the students solve the given simultaneous equations and are asked to guess the relationship between the geometric expressions above the question and the equations. Through the activities, they may try to figure out this relationship and verify their conjectures. Finally, the students would be able to find the relations between the numbers of the intersection in between the circle and the lines and one of the roots in the equations. We do not think that the example completely consists of the all kinds of activities including ‘generalizing’ or ‘extension to new-complex situation’. Contrary to the others examples, however, the activity would provide students with opportunities to figure out relationships between geometry and algebra.

4.2. Korean Mathematics Teachers’ Concern

Korean Teachers’ Concern on Integrating Technology into Mathematics Classroom

As depicted in Table 4.1, the matrix was organized which cross-tabulated each participant’s highest and second highest stage of concern. Figure 4.12 displayed a line chart of the averaged percentiles for the total group and represented the group’s concern profile. Results for the responses revealed the following.

Firstly, the highest peak Stage of Concern was the Awareness Stage (Stage 0) with 51.1% of the respondents having this stage as their peak stage. [9]’s study mentioned that data should be analyzed in relation to the second highest stage of concern and each item at the peak stage when the highest stage of concern was Awareness concerns. According to their suggestions, analysis of this study indicated the percent of individuals with intense management concerns was 55.1 % of the total teachers with highest stage of concern Awareness. 29.7% teachers at peak SoC Awareness were concerned informational sides as their second highest SoC. The results of each item analysis at Stage 0 showed that the items involved interests on using technology had lower scores of concern, but the question about using others teaching methods instead of technology had higher scores. By dwelling upon data of the second highest SoC and items at Stage 0, the results showed that Korean teachers had intense concerns to teach mathematics with other teaching materials instead of technology due to lack of knowledge or awareness about informational and management aspects of using technology in mathematics classroom.

Table 4.1: Distribution of second-highest stage of concern in relation to the participants’ highest stage of concern

Highest Stage of concern	Second highest stage of concern score							
	0	1	2	3	4	5	6	Totals
0 Awareness	0	35	16	65	0	1	1	118
1 Informational	16	0	21	21	1	2	9	70
2 Personal	0	3	0	1	0	0	0	4
3 Management	17	17	2	0	0	1	0	37
4 Consequence	0	0	0	0	0	0	0	0
5 Collaboration	0	0	0	0	0	0	0	0
6 Refocusing	0	2	0	0	0	0	0	2
								231

Secondly, Personal Concern (Stage 2) displayed a relatively low level of concern, compared with Information (Stage 1) or Management Concern (Stage 3). At the beginning step of an innovation in education, teachers have high level of Personal Concern with Awareness and Informational Stage and are not convinced of their professional role or ability in educational changes ([1], [5], [7], [20]) Korean mathematics teachers, unlike the earlier studies, had intense Management and indifferent Personal concern even though the innovation was still at an initial stage. The participants of this study, to put it more concretely, had a relatively low negative perception on accordance with their professional role or ability to make use of technology in teaching mathematics. Rather, the teachers are concerned about not having enough time to prepare lessons including technology and spending time with nonacademic problems related to technology. In other words, they have already considered actual situations when they teach mathematics using technology in their classrooms.

Thirdly, Consequence (Stage 4), Collaboration (Stage 5) and Refocusing Concern (Stage 6) presented lower levels of concern compared with the others. The result revealed typical trends or patterns of teachers' concern at the early steps of educational innovation ([20]). Until now, the teachers have not considered those stages of concern, from the impact use has on students; the collaboration with teachers or community; the way to change innovation is used. CBAM authors explained a teacher with high Stage 4, 5 and 6 had a variety of experience with innovation. It means Korean mathematics teachers lacked experience of using technology in mathematics classroom in order to focus on the stages of concern, such as Consequence, Collaboration and Refocusing Concern.

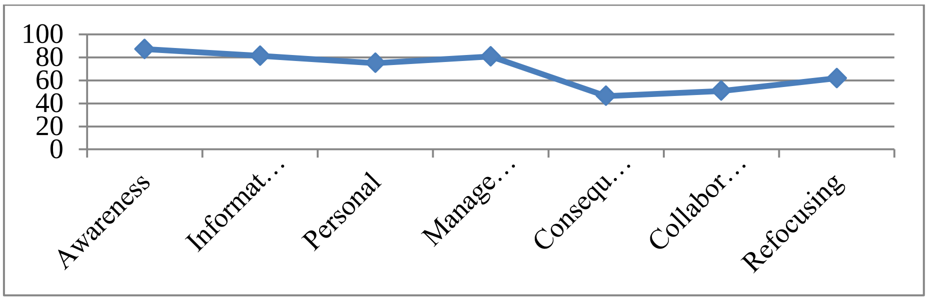


Figure 4.12 Participants' Stages of Concern profile (N=231)

Finally, Korean mathematics teachers had positive perspectives on the use of technology in mathematics education, but various degrees of doubt and potential resistance to integrating technology into mathematics classroom. [10] noted that individuals had negative attitude about innovation when Personal Concern displayed higher level of concern than Informational Concern at stages of concern profile like Figure 3.1. Additionally, they explained 'tailing-up of Stage 6' was taken as a potential warning that there may be resistance the innovation on the part of the respondent. Figure 4.12 revealed that the respondents displayed a relationship between Personal and Informational Concern and phenomena of tailing-up of Stage 6. The results of analysis, as it were, showed that Korean teachers had positive views on using technology in teaching and learning mathematics. However, it may be difficult for the teachers to integrate technology into their classrooms because of their potential resistance.

4.3. Korean Mathematics Teachers' Concern according to Level of using Technology

Korean Teachers' Use of Technology in Mathematics Classroom

The levels of using technology were categorized into six degrees which were differentiated based on the participants' answers. The results are listed below at Figure 4.13.

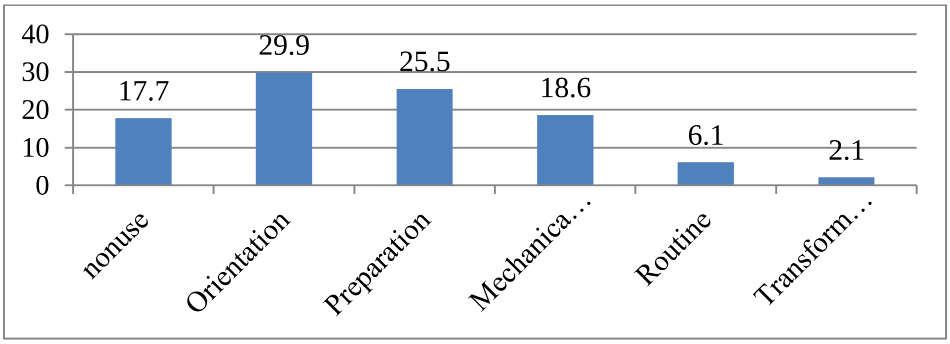


Figure 4.13 the Levels of Use of Technology in Mathematics Classroom (N=231)

73.2% of the total respondents have not been using technology in teaching mathematics, and 26.8% of the participants of this survey have already applied technology to their teaching mathematics. Moreover, the percent of teachers with Preparation LoU was 25.5% and they would like to teach mathematics with technology in the near future. It means that 52.3% of the total respondents have decided to make use of technology in mathematics classroom or already applied technology to their teaching mathematics. At least 82.3% of the teachers already got information about technology in mathematics education. According to [8], a teacher is able to continue using innovation when he or she is at least beyond the level of Mechanical Use. Namely, 26.8% of the teachers had the ability to make use of technology in practice. The respondents with Mechanical LoU mainly used technology without students' activities and the teachers with Routine LoU made use of existing materials without their own modification or development of activities. It means that only 2.1% of the total individuals can modify and develop activities or material with their purpose for teaching mathematics with technology.

Stages of Concern data were analyzed according to teachers' LoU of technology in order to accelerate use of technology in mathematics classroom through individualized interventions or supports. The results of the analysis are as follows (See Figure 4.14, Figure 4.15 and Figure 4.16).

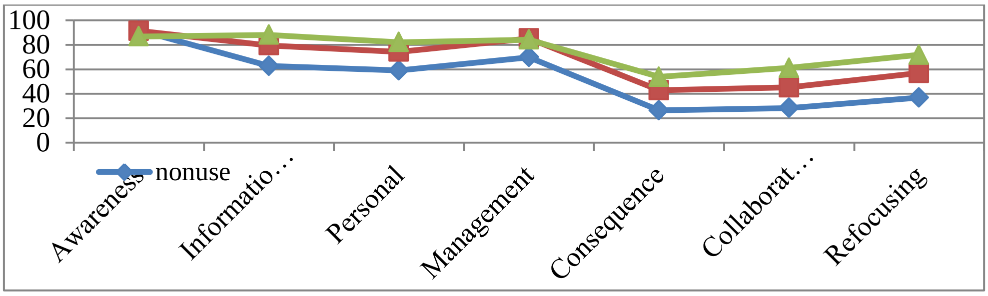


Figure 4.14 Non-User Teachers' Stages of Concern

Figure 4.14 displays non-user - Nonuse, Orientation and Preparation - teachers' stages of concern profiles. Generally, teachers have intense concern of Awareness, Informational and Personal stages at the earlier steps of an innovation. The data of this study have produced similar results, but there is a little different result of between previous studies and this study. According to non-user teachers' SoC in this paper, teachers' concerns in the stage of Management were more intense than those in stages of Informational and Personal concern. This may relate to the current status of the teachers' concern about plan or manage to integrate technology into mathematics classroom without their own experience in practice. In other words, non-user teachers might find it difficult to manage or control lessons with technology due to barriers and constraints, such as classroom environments or time; even they have not ever tried to integrate technology into the classroom.

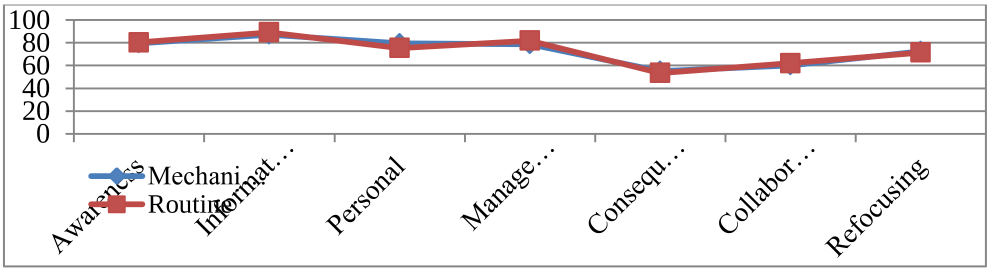


Figure 4.15 Mechanical Use and Routine Teachers' Stages of Concern

Figure 4.15 indicates that the profile of each of the two subgroups in this study (Mechanical Use and Routine) respectively showed lower intense concerns about Awareness, when compared to non-user groups' stage of Awareness. However, the teachers in Figure 4.15 still had intense concerns of Informational, Personal concerns. The profiles of teachers in Figure 4.15 are analogous to that of Preparation teachers who have only plan to make use of technology in the lessons. [25] mentioned that SoC is not hierarchical, and when a teacher moves out of one stage, they still may have concerns consistent with previous stages. Thus, the teacher need appropriate interventions or supports by analysis of current teachers' SoC dependent on their levels of an innovation use ([22],

[24]). In view of these studies, the participants of this study, especially Mechanical and Routine use levels, had very high intense concerns of Informational and Management Stages even if they have already applied new teaching methods with technology to their classrooms. The result revealed that the teachers should not have received apposite interventions or supports according to their levels of technology use.

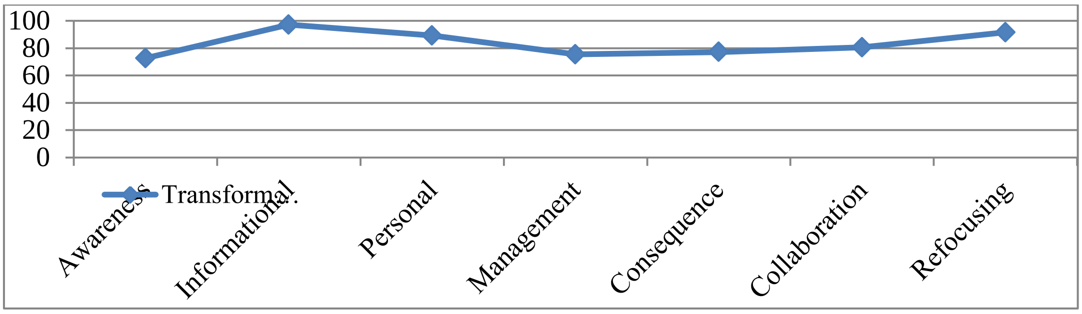


Figure 4.16 Transformation Teachers' Stages of Concern

According to Figure 4.16, Korean mathematics teachers with Transformation LoU still had intense Informational concern, but also had very intense concern of Refocusing stages unlike other LoU teachers. Teachers with high Stage 1 and Stage 6 were interested in new teaching methods using technology, and needed appropriate interventions or supports to learn the teaching skills ([9]). Therefore, the data in Figure 4.16 revealed that the teachers are concerned about ways to supplement and vary their previous teaching methods with technology through experts' supports.
A one-way ANOVA was conducted to determine if there was a statistical significance in means between the dependent variables, teachers' levels of using technology(levels 0-5), and the independent variable, experiences related technology (learning or training experience). The independent variable, the experiences, had two levels, learning in college or attending at training program. The result for the ANOVA in Table 4.2 was statistically significance for the experiences related learning or training technology.

Table 4.2: ANOVA results on Participants' LoU as experiences related technology

	Sum of Squares	df	Mean Squares	*F*	Sig.
Between Groups	31.008	2	15.504	10.787	.000
Within Groups	327.702	228	1.437		
Total	358.710	230			

5. Discussion

The Role of Technology in Korean secondary mathematics textbooks
Research question 1 in this study has only dealt with the analysis of Korean secondary mathematics textbooks.

In the data, technology in Korean mathematics textbooks of senior levels is mainly focused on using it in a technical role more than a conceptual one. Moreover, the conceptual role of technology consisted of mainly the use of 'E', and the activity of 'E-V' was the second largest proportion after 'E in both Korean junior and the senior secondary mathematics textbooks. The crucial advantages of using technology in mathematics education is that technology can provide students with opportunities to foster conjecturing and generalizing during problem solving or understanding of mathematical concepts. [3] suggested that processes of conjecture, argumentation and validation are included in activities with technology in order to develop students' understanding in the contrast to earlier approaches as the teacher-directed explanations. According to [12]'s study, allowing the students to explore figures, via conjecturing and testing of their conjecture, in more generalized visual setting using technology appeared to have enabled the students to form better concept-images. Therefore, it is not desirable for students, given that the activities in the textbooks, Exploring (E) and Exploring-Verifying (E-V), do not allow for students to conjecture mathematical concept for themselves based on their intuition or exploration and to verify whether it is right.

Korean Mathematics Teachers' Concern and Use of Technology
Research question 2 and 3 in this study has analyzed Korean secondary mathematics teachers' concern about technology integration in the classroom.

In the survey of Research question 2, the teachers have high level of Awareness Concerns with Informational and Management Stages, and Consequence (Stage 4), Collaboration (Stage 5) and Refocusing Concern (Stage 6) presented lower levels of concern compared to the others. It means that Korean mathematics teachers' use of technology in teaching mathematics is currently in the early steps of introducing technology in mathematics education. Several related studies conducted about CBAM reported similar results ([5], [7], [9]). Given teachers' perspectives on the use of technology in mathematics education, Korean mathematics teachers had positive standpoints on technology integration. The participants of this study had a relatively low negative perception on accordance with their professional role or ability to make use of technology in teaching mathematics. [10] noted that individuals had negative attitude about innovation when Personal Concern displayed higher level of concern than Informational Concern at stages of concern profile. However, Korean mathematics teachers, unlike the earlier studies ([1], [5], [7], [20]), revealed that the respondents' Personal Concern displayed lower level of concern than Informational Concern. By the analysis in Research question 3, Korean mathematics teachers in the study revealed different patterns and trends of concerns on technology integration depending on their levels of using technology. According to [22] and [24], the teachers needed apposite interventions or supports, especially depending on their levels of technology use, to effectively utilize it in mathematics lessons, building their own experiences on adopting and inviting technology into the classroom.

6. Conclusion, limitations, and future directions

In this paper we attempted to investigate the causes of why technology has not been integrated into mathematics teaching by teachers. We considered two aspects of the causes; Korean mathematics textbooks and teachers. According to the data of the textbooks, the integration of technology in mathematical activities has fallen short of our expectations even though Korean mathematics curriculum emphasized on the application scope of technology use in learning and teaching mathematics over the past 20 years. In the teachers' data, we found that mathematics teachers needed appropriate interventions or supports to integrate technology into teaching mathematics. However, we could not fully perceive the meaning of the teachers' demand for using technology due to limitations of quantitative survey. We would like to analyze teachers' concerns by a case study depending on their levels of using technology in teachers' practice. The research may help us get in more detail pedagogical implications for using technology into mathematics teaching and learning. Additionally, for successful integration of technology into mathematics classroom, educational researchers or administrators should help teachers move toward more practical use of technology without emotional or physical barriers in mathematics classroom.

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