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An Analysis of the Mathematical Tasks in the Korean Seventh Grade Mathematics Textbooks and Workbook[1]

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The Korean mathematical curriculum has been changed three times during the resent five years. It led to changes in textbook system. In the 2007 revised mathematics curriculum, workbook was developed focusing on student's self-oriented learning, effective practice in differentiated classroom, and mathematics problem solving considering individual difference. This paper examines the characteristics of the tasks and the way the tasks are organized in the textbooks and the workbook in accordance with the 2007 revised mathematics curriculum; comparing with the function section before and after the amendment. Researchers examine whether the textbook and workbook were accomplished the purpose with "cognitive expectation", "level of cognitive demand", "and "response types". Researchers revised framework of [Son, J. W. & Senk, S. (2010). How reform curricula in the USA and Korea present multiplication and division of fraction. *Educ. Stud. Math* **74(2)**, 117–142] to make them suitable for the function section at the seventh grade.

Keywords: cognitive expectation, level of cognitive demand, response types, mathematical tasks
MESC Classification: U20
MSC2010 Classification: 97U20

1. INTRODUCTION

[1] A draft version of the article was presented at the KSME 2012 Spring Conference on Mathematics Education held at Seoul Nat'l University, Seoul, Korea; April 6–7, 2012 (*cf.* Cho & Kwon, 2012).

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The seventh mathematics curriculum had taken effect during ten years from 2001 in secondary school level. The seventh mathematics curriculum in Korea has been acknowledged as an advanced curriculum because it allowed students to progress at level of their ability and it was learner-centered. However, in only few cases has the intent of the seventh mathematics curriculum been fulfilled in mathematics classroom due to the difficulty of applying the curriculum to real situations, therefore it has led to the amendment of the seventh mathematics curriculum. The 2007 revised mathematics curriculum was intended to make it possible to carry out the basic aims of the seventh mathematics curriculum in mathematics classroom. There was a variety of changes, For example, the term 'stage' was replaced by 'grade' or 'semester', and the differentiated instruction was emphasized in the classroom. As a supplementary textbook, a workbook was adopted in the amendment of the seventh mathematics curriculum, and it was to be used in conjunction with the main textbook in the so called "1+1" system. Workbook was developed focusing on students' self-oriented learning and differentiated instruction. Suh (2011) maintains the background of developing direction of workbook as invigoration the differentiated instruction, effective practice in differentiated classroom, and mathematics problem solving considering individual difference. So far, there have been few researches on the characteristics of the tasks for the differentiated instruction, self-directed learning, and the way they are organized in the textbook and workbook. The purpose of this study was to examine the characteristics of the tasks and the way the tasks are organized in the textbooks and the workbook in accordance with the amendment of the seventh mathematics curriculum. Researchers examine whether the textbook and workbook offer diverse learning opportunity to students with "cognitive expectation", "level of cognitive demand", and "response types." Researchers revised the framework which is used by Son & Senk (2010) to make them suitable for the functions section at the seventh grade. As such, this research is expected to contribute to more effective usage of the reformed textbook for teachers and learners by providing productive information on the reformed textbook as well as workbook and also to provide meaningful issues and suggestions for the development of the textbook and workbook in next curriculum. The research question guided in this study was: What changes have been made in the tasks in textbooks and workbook, especially in the functions section, as a result of the amendment of the seventh mathematics curriculum?

2. LITERATURE REVIEW

Doyle (1983) defined academic tasks as:

(a) Products that students are to formulate, such as an original essay or answers to a set of test questions;

(b) The operations that are to be used to generate the product, such as memorizing a list of words or classifying examples of a concept; and

(c) The “givens” or resources available to students while they are generating a product, such as a model of a finished resource supplied by teachers or a fellow student.

Such tasks play an important part in helping students get accustomed to, develop, utilize and understand a certain concept in a mathematical way because concepts influence learners by directing their attention to a particular aspect of content and by specifying ways of processing information (Stein, Grover & Henningsen, 1996).

In this study, a mathematical task is defined as a mathematical object contained in textbooks or workbooks that makes students interested in a certain mathematical concept or that students are to answer and solve using logical thinking in direct or indirect ways. Mathematical tasks in this research include examples, activities, exercises and problems.

2.1. Related research on textbook analysis

Various aspects of the tasks presented in the textbooks and the workbook have been researched. For example, Son & Senk (2010) analyzed the learning-opportunity aspect of the tasks. Ubuz, Erbas¸ Cetinkaya & Özgeldi (2010) compared the characteristics of the tasks contained in the textbooks of two countries, interpreted the differences in students' achievements, and suggested directions for the improvement of the textbooks and the curricula. Jone & Tarr (2007) researched the trend of the task transition from a historical viewpoint. Also, a research on the transformation of the tasks for the reform-oriented classroom has been conducted.

Li (2000) designed a three-dimensional framework consisting of “mathematical features,” “contextual features” and “performance requirements” for a cross-national comparison research on the problems presented in the textbooks. Li (2000) specified the dimension of performance requirements according to

(a) Response type, and

(b) Cognitive requirement.

By combining of the work of Li (2000) and NCTM (2000)’s process standard, Son & Senk (2010) examined the problems on algebraic fractions contained in Korean and US textbooks, with respect to the cognitive expectation which consists of conceptual knowledge, procedural knowledge, problem solving, representation, and mathematical reasoning. They claimed that there were five important aspects of mathematical tasks, which are:

(1) Required single procedure, multiple procedure,

(2) Purely mathematical context, illustrative context,

(3) Numerical answer only, numerical expression only, explanation,

(4) Cognitive expectation, and

(5) Level of cognitive demand.

Level of cognitive demand (LCD) is the kind and level of thinking required of students to successfully engage with and solve a particular task (Stein, Smith, Henningsen, & Silver, 2000). LCD has been a standard to evaluate the quality of mathematical tasks in cross-national textbook comparison researches. For instance Ubuz, Erbas¸ Cetinkaya & Özgeldi (2010) examined the LCD in the algebraic tasks provided in national elementary mathematics textbooks. They suggested teachers, administrators, and textbook publishers to provide more higher-level of LCD tasks in textbooks. Jone & Tarr (2007) examined the levels of cognitive demand required by probability tasks in middle grades mathematics textbooks from a historical perspective. Kang (2007) analyzed probability problems in Korean, US, and Singaporean textbooks using LCD.

Webb (1999) developed Depth-Of-Knowledge (DOK), which is analogous to LCD. Webb's model has been widely applied as a guide for creating questions for state assessments and for checking the alignment among content areas, classroom activities, and assessment. In dealing with such cognitive levels, it is necessary to be aware of the following: First, when evaluating the level of cognitive demand, it does not necessarily mean that the textbook and the workbook should provide problems only of a higher level. Instead, it is desirable for various levels of tasks to be offered. Second, it is necessary to consider the practical level of cognitive rather than superficiality. In other words, tasks utilizing representatives or pictures, real-life problems, or problems requiring multiple steps are not always of a higher level. Conversely, typical type problems in the textbooks are not necessarily of a lower level (Kim, 2005).

2.2. Framework

A mathematical task means mathematical object that provides the knowledge for students to develop mathematical thinking and makes students interested in a certain mathematical concept. Therefore mathematical tasks are comprehensive of questions, problems, and activities in which students participate. In this research, mathematical task is defined as examples, activities, exercises and problems contained in textbooks and workbook.

Son & Senk (2010) explain that there were five important aspects of mathematical tasks, which are:

(1) Mathematical feature,

(2) Context,

(3) Response types,

(4) Cognitive expectation, and

(5) Level of cognitive demand.

Since the 7th mathematical curriculum and the amendment of 7th mathematical curriculum have emphasized the development of the mathematical thinking powers and solving a real-world mathematics problem, then mathematical feature and contextual feature are not examined. In this research, after the authors scrutinized the frameworks used in the precedent researches, researchers analyzed the characteristics of problems and the organization of the textbooks and workbook based on the following three important criteria:

(1) Cognitive expectation,

(2) Level of cognitive demand, and

(3) Response types.

Cognitive expectation is cognitive performance what the tasks require (Li, 2000). Son and Senk (2010) subdivided the cognitive expectation into five criteria: a conceptual knowledge, a procedural knowledge, a problem-solving, a representation, and a mathematical reasoning. Because mathematical reasoning, mathematical communication, and problem solving have been emphasized in Korea and a mathematical reasoning and a problem solving are already included in cognitive expectation criteria, the authors added a mathematical communication as sixth cognitive expectation criteria. The above mentioned three components are called “mathematical process” in future-oriented mathematical curriculum and emphasized as standards of achievement.

Table 1. Framework of Cognitive Expectation

Criteria		*Coding*
Knowing	Conceptual Understanding	C
	Procedural Practice	P
Representation		R
Problem solving		PS
Mathematical Communication		MC
Mathematical Reasoning		MR

Conceptual knowledge requires the student to do nothing more than answer a question about the concept itself. The student is not required to perform computation of any kind but is instead only required to call upon the meaning of the function or any underlying concept. Procedural knowledge engages students in using procedures or algorithms. Representation requires students to be able to interpret and describe any mathematical object by a mathematical formula, graph, diagram or symbol. Problem solving requires the student to solve problems both with a real-life context and a mathematical context. Plus, problems that require the student to understand the real-life context are also categorized in problem solving. Mathematical reasoning requires students to explain or justify their own solutions.

The practical level of cognitive thinking was highly considered in analyzing the cognitive expectation rather than appeared in the surface. Stein, Grover & Henningsen (1996) divided tasks into low-level and high-level task types. Webb (2002)'s cognitive demand for doing math has the following 4 levels: recall, skill/concept, strategic thinking, and extended thinking. Researchers designed a 4-level framework for functions section at 7th grade.

Table 2. Framework of depth of knowledge

Framework	*Criteria*	*Coding*
Depth of Knowledge	Level 1 − this level involves the recall of information(fact, definition, term or property) and simple operation. − identify information in task − points in a graph	1
	Level 2 − able to make an observation and interpret data − interpret or utilize a diagram, graph, and formula to represent − mathematical concept − solving a problem using multiple concepts − using a simple formula or getting a relation with variables known − getting a relation from a correspondence diagram, drawing a graph	2
	Level 3 − solving a problem by producing concrete data − multi-step problem − justification − express phenomena mathematically, interpret mathematical expression	3
	Level 4 − explain one's idea in a situation that multiple answers are allowed − finding mathematical concept in daily life	4

Level 1 includes the recall of information such as a fact, definition, term, or a simple procedure, as well as the performing of a simple algorithm or operation, and the application of a formula. That is, a one-step and straight algorithmic procedure should be included at this lowest level. Level 1 task include “finding the value of a given function, finding the domain and range of a given function, deciding in which quadrant a given ordered pair is located, locating an ordered pair in the plane, and filling out blanks in a given diagram.

In order to solve level 2 tasks, several skills are required. Making observations of data; using or interpreting a diagram, a graph, and a formula in order to express mathematical concepts; using a simple mathematical theorem; and finding a mathematical relation when the relation between variables is known are the tasks performed in this level. For example, the theorem to calculate the area of triangles, finding a mathematical relation using the theorem for distance-speed, and discovering a mathematical relation from a given diagram is included.

Level 3 tasks require reasoning, strategic thinking, and a higher level of thinking than the previous two levels. These actions imply processes requiring more than one step. Solving a task by generating data, describing phenomena in a mathematical language, interpreting mathematical expressions, deducing the pattern of lines with varying slope, creating a diagram and drawing a mathematical relation based on the diagram, and arriving at a formula by finding a relation between variables are the required tasks.

Level 4 tasks require students to explain their thinking when more than one correct answer is possible, and to relate mathematical concepts to the real world in new situations. For example, finding a situation in everyday life which can be represented by a function is included.

Interpreting and assigning this framework to both objectives within standards and assessment items is an essential requirement of this alignment analysis. The researchers agreed that these levels and types were adequate for the purpose of comparing the standards with the assessments. The analysis helped the researchers to clarify how they used the different levels and types.

By analyzing the response types of tasks, Researchers can identify whether the task requires a result of the thinking process or the process itself. According to Li (2000), there are three types of response type tasks:

(1) Numerical answer only,

(2) Numerical expression only, and

(3) Explanation or solution required.

In this research, we extended Li's framework so as to be suitable for the functions section, which consists of:

(1) Multiple-choice questions,

(2) Short-answer questions, and

(3) Sentence-answer questions.

It should be noted that the multiple-choice type has a subcategory.

Table 3. Framework of Response Type

	Criteria	*Coding*
Multiple choice	Type1: True or False problem, problems with options indispensible	1.1
	Type2: problems making sense with options	1.2
Short	Type1: numerical only	2.1
	Type2: problems requiring mathematical notation in answer	2.2
	Type3: problems requiring mathematical terms in answer, T/F	2.3
	Type4: making a correspondence diagram	2.4
Open-ended	Problems requiring process or explanation of one's thought	3

Researchers labeled the question as 1.1 if each choice in the problem can be transformed into a true or false question. Also, a problem that requires students to solve the problem and to select an answer among the choices is coded as 1.2. Each choice in the Type 1.2 problems cannot be an independent question in itself in contrast to Type 1.1 problems. As for the short-answer question type, tasks requiring

(1) A numerical answer,

(2) A mathematical expression,

(3) A diagram or a graph, and

(4) Simple words are coded as 2.1, 2.2, 2.3, and 2.4, respectively.

3. RESEARCH METHOD

The data used for this study come from the relevant lessons on functions in two Korean textbooks before and after the 7th amendment. The textbooks we selected are the most popular in Korea. Three graduate students majoring in mathematics education coded the tasks presented in the introduction of functions according to the framework we developed. Researchers repeatedly revised frameworks and coded the tasks until researchers were unanimous about each task. While it was easy enough to code tasks by response type, it was sometimes difficult to code tasks as cognitive expectation or level of cognitive demand. If it was apparent that a certain cognitive expectation researchers demanded the most in a task, coded this task as the most crucial aspect demanded. In cases where the task required more than two aspects equally, researchers used double coding. For example, consider the question "Find the range of a function" for which a function is given. Researchers double coded this task as both "C" and "R" because it demands not only concept knowledge about the function but also procedural knowledge to find the values of the given function. Also, Researchers considered the highest level of demand in coding problems asking more than two questions, and each sub-problem under a main problem was counted as one task.

Table 4. Sample textbook tasks coding with respect to the three frameworks

Examples	*Coding*		
	CE	DOK	RT
1. Problem no. 2 on p.144 in the text before the amendment • In a garbage incineration plant, 240mg of dioxin is produced when 10000 tons of garbage is burned. If x ton of garbage is burned, then y mg of dioxin produced. Find the relation between x and y.	PS	Level 3	2.2
2. Problem no. 2 on p.135 in the text after the amendment • Draw a graph of $y = -2x$	R	Level 2	2.4
3. Problem no. 5 on p.132 in the text after the amendment • Decide which quadrant are the following points in (1) $A(-2,-6)$ (2) $B(-2,6)$	C	Level 1	2.3
4. Discussion on p.132 in the text after the amendment • Explain why we call an "ordered pair" rather than a "pair" $(2,3),(6,2)$	MR	Level 4	3
5. p.125 exercise no. 10 in p.125 in workbook • Find all point on the graph of $y = \frac{3}{2}x$ (1) $(0,1)$ (2) $(4,6)$ (3) $(2,-3)$ (4) $(-2,-3)$ (5) $(-3,2)$	P	Level 1	1.1
6. Fnal test on p.131 in workbook • $y = \frac{4}{3}x$ what is when $f(-3)$? ① -8 ② -4 ③ -1 ④ 4 ⑤ 8	P	Level 1	1.2

4. RESULTS

The number of tasks decreased by about 20 percent following the amendment of the 7th mathematics curriculum textbook; more specifically, while the 7th mathematics curriculum textbook (KM1) contained 120 tasks; the amendment (KM2-1) contained 97 tasks. However, many tasks are included in the workbook (KM2-2), and the 248 tasks provide students with twice the learning opportunity as before. The 97 tasks, which account for 40 percent of the total number of tasks, are presented in the textbook (KM2-1); meanwhile, 151 tasks, nearly 60 percent of the total task amount, are presented in the workbook (KM2-2).

Table 5. Number of tasks in textbooks and workbook

	Textbook of the 7th mathematics curriculum (KM1)	Textbook of the amendment of the 7th mathematics curriculum (KM2-1)	Workbook of the amendment of the 7th mathematics curriculum (KM2-2)
Number	120	97	151
	120	248	

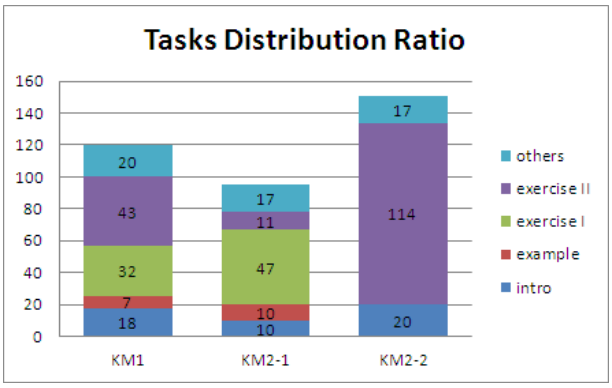

Figure 1. Distribution and number of tasks according to organization of the textbooks and the workbook

In order to analyze the textbooks in the sense of task organization, we divided sections in the textbook into introduction, example, exercise I, exercise II, and others. Exercise I is a similar task to example placed right after example, and exercise II is a task placed at the end of each chapter. Task in others section cannot be included by the above categories, which is a task to explain concept so as to solve a problem or to contain mathematical reasoning.

A comparison of the number of exercise II between KM1 and KM2 shows that the number of tasks increased, from 36.7% (43 tasks) to 50.4% (125 tasks). In the comparison of KM2-1 and KM1, it is observed that the total number of tasks in the textbook has decreased but the number of examples and exercises I has increased. Also it is notable fact that the weight of exercise II in the amended textbooks is down to 11% (11 tasks) from 36.7% (43 tasks) in 7th mathematics curriculum textbook, while the workbook contains nearly 75% (114 tasks) of the tasks in exercise II.

4.1. Cognitive expectation

Figure 2 and figure 3 show the percent and numbers of tasks according to cognitive expectation in the textbook and in the amended textbook and workbook. The values of the figure 2 and figure 3 mean the number of tasks in each cognitive expectation's sub-category. In the KM1, there are 71 representation tasks, which comprise a large proportion of the cognitive expectation tasks. After the amendment, representation is also the most frequent type of task found in the textbook and workbook. In the KM1, 51% tasks (71 tasks) fell under representation, but in KM2, the rate of representation tasks decreased to 44% (109 tasks) while the rate of conceptual procedural knowledge tasks increased. The distribution of representation tasks in the workbook decreased to 38% (58 tasks), while the distribution of conceptual knowledge, procedural knowledge, and problem-solving tasks increased. The introductory section of KM1 contains problem-solving (PS) and mathematical reasoning (MR) tasks, but the introductory section in KM2-1 contains only procedural knowledge (P) and representation tasks.

Figure 4, 5 illustrates the distribution of cognitive expectation in intro, example, exercise I, II, and others sections. In KM2-1, problem-solving and mathematical reasoning tasks appear in exercises II and others section, which are found in the later parts of the textbook. Especially focusing on the others section conceptual knowledge and procedural knowledge tasks compose more than 40% of the others section in KM1. However, the number of conceptual knowledge and procedural knowledge tasks has remarkably decreased in KM2's others section, and problem-solving tasks and mathematical reasoning tasks increased in KM2's others section.

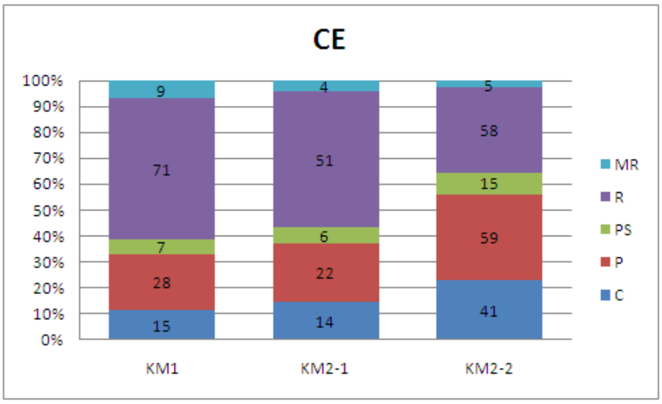

Figure 2. Percent of tasks according to cognitive expectation

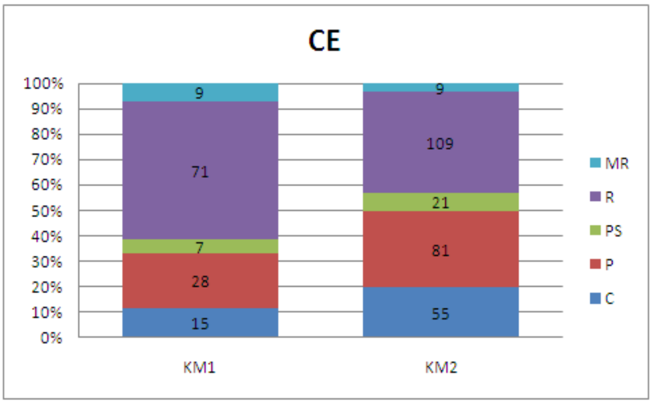

Figure 3. Percent of tasks according to cognitive expectation

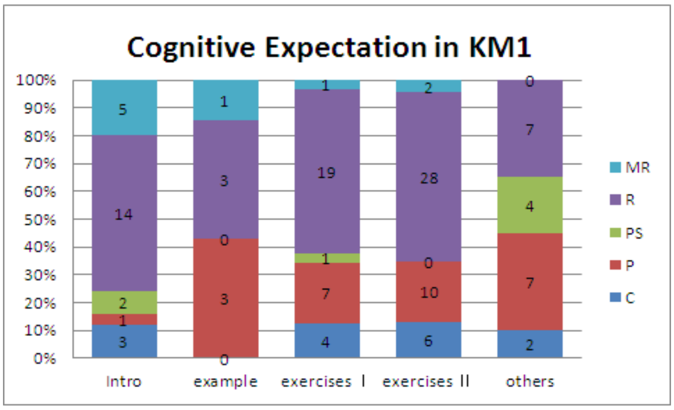

Figure 4. Cognitive expectation in KM1

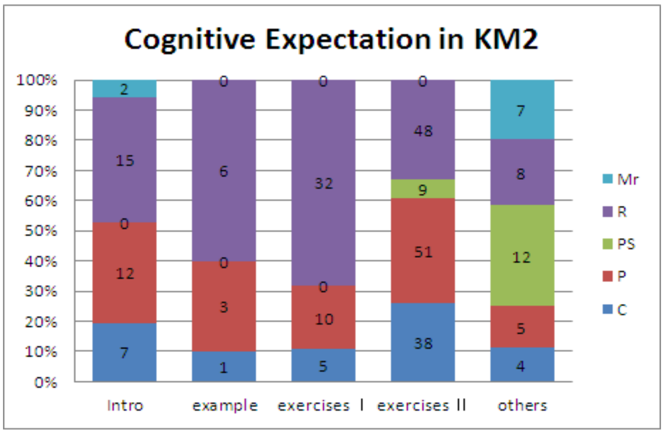

Figure 5. Cognitive expectation in KM2

Mathematical reasoning tasks in KM1 appeared from the introduction to exercises II however, in KM2-1, they appeared only in the etc. section and composed 24% (4 tasks) of the 17 tasks. The others section of the textbook contains the tasks that lead the student to voluntarily participate in classroom discussion, to plan strategies and to solve problems. Therefore, the ratio of mathematical reasoning tasks is relatively high in the others section. Conceptual knowledge is emphasized at the beginning of the KM2 textbook and problem-solving tasks and reasoning tasks are presented in the later parts of the textbook. It seems KM2-1 has taken into consideration how to make it easier for students to approach a new concept.

The introductory section in KM2-1 consists of only procedural knowledge tasks and representation tasks. However, the introductory section in KM2 contains various types of tasks, namely cognitive expectation-conceptual knowledge, procedural knowledge representation, and mathematical reasoning tasks. The introductory section of KM2-2 consists of tasks which test prerequisite learning and require various types of cognitive knowledge.

4.2. Depth of knowledge

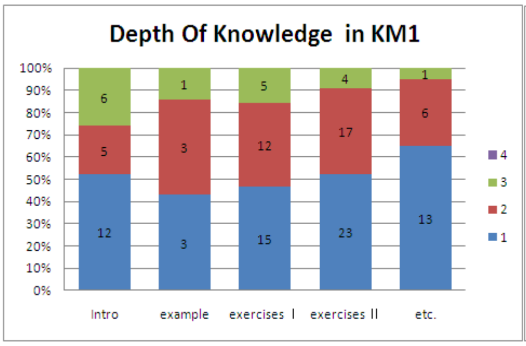

Figure 6. Depth of knowledge in KM1

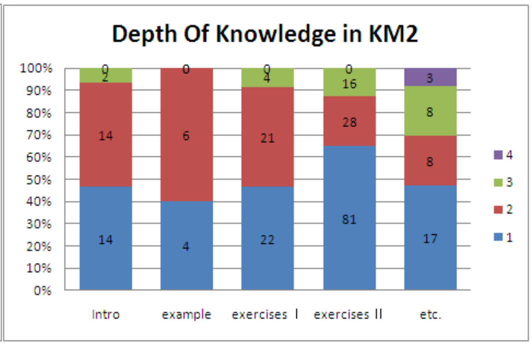

Figure 7. Depth of knowledge in KM2

Figures 6 and 7 illustrate the level of difficulties according to task organizations before and after the amendment. Before the amendment, level 3 tasks composed 23% (7 tasks) of the tasks in the introductory section and examples, but in the amended textbook, only level 1 and level 2 (99.5%) tasks are found in the introductory section. Especially, the examples require level 2 tasks and the ratio of level 1 to level 2 tasks is four to six. According to the priority of the sections in KM1 and KM2, the weight of level 1 tasks in the introduction, examples, and exercises I sections are maintained from KM1 to KM2. The weight of level 2 tasks in these sections of KM2 has increased compared to KM1. The ratio of level 1 and level 3 tasks in exercises II has increased, but that of level 2 tasks in exercises II has decreased.

Levels 1 and 2 are considered low-level cognitive demand tasks, and levels 3 and 4 are considered high-level cognitive demand tasks. The weight of high-level cognitive demand tasks has increased in the exercises II section in KM2 compared with KM1. The composition of depth of knowledge tasks has not changed after the amendment. However, the number of tasks in levels 3 and 4 in KM2 is 4 times as great as the number of levels 3 and 4 tasks in KM1.

Also, in KM2, levels 3 and 4 tasks account for nearly 30% of the etc. section tasks. Given that levels 3 and 4 tasks compose less than 10% of the tasks in the etc. section of KM1, this is a significant change. Particularly, it is worth noticing that the level 4 tasks appear after the amendment in other section.

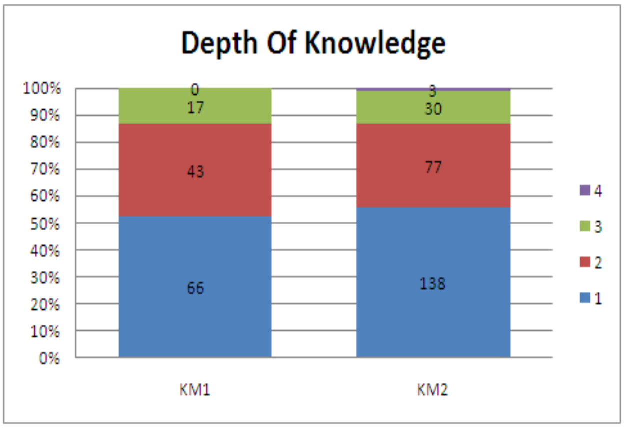

Figure 8. Percent of tasks according to DOK

However there is not significant change in the distribution of tasks according to levels following the revision. However, in KM2, twice as many tasks as KM1 can be found. Additionally, before the amendment, there were 17 levels 3 and 4 tasks; after the amendment, the number of such tasks was increased to 33.

4.3. Response type

Figure 9 shows the distribution of tasks according to response type used in the functions section in the 7th grade textbooks and workbook. There is a percent difference of multiple-choice problems between the textbooks and the workbook. Compared to KM1 and KM2, the workbook provides a much higher percent of multiple-choice problems (21%, 33 tasks) than KM1(5%, 7 tasks) and KM2 (2%, 2 tasks). Regarding the distribution of 1.1 type and 1.2 type problems, the workbook provides more 1.1 type problems (12%, 19 tasks) than KM1 (0.7%, 1task) and KM2 (1%, 1task). It also provides more 1.2

type problems (9%, 14 problems) than KM1 (about 4.3%, 6 problems) and KM2 (1%, 1task).

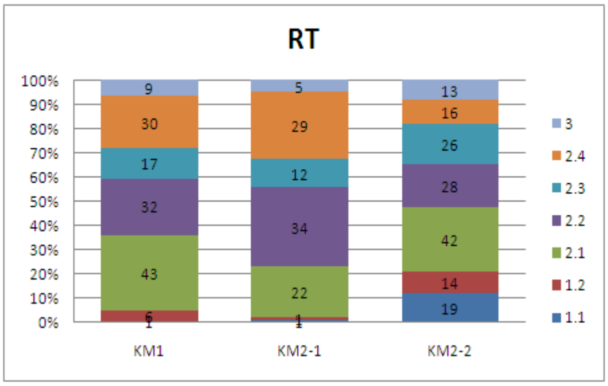

Figure 9. Percent of tasks according to response types

On the other hand, in the case of single-answer tasks, there is a small difference in the percent among KM1 (88%, 122 tasks), KM2 (93%, 87 tasks) and the workbook (71%, 112 tasks). Considering the fact that the total number of the tasks in KM2 and the workbook is nearly double that of KM1, the difference of the percent among KM1, KM2, and the workbook is not very meaningful. In the case of write-out answer problems, similar results are observed.

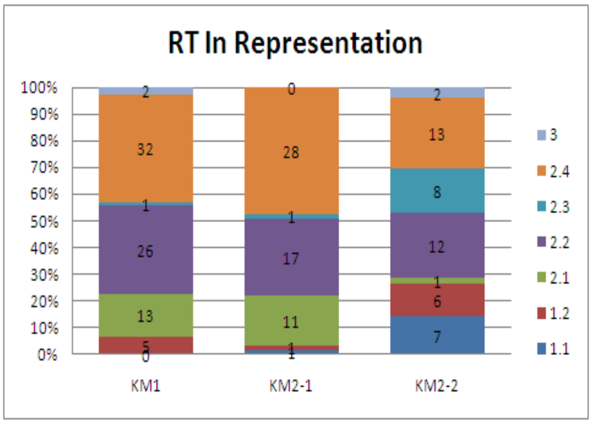

Figure 10. Percent of tasks according to response type in representation

Figure 10 illustrates the response type distribution of tasks in representation. Overall, the workbook shows more balanced distribution of tasks of different response types. Such balanced distribution is reconfirmed by a graph of the distribution of tasks by response type based on the classification of knowledge expectation. The following table shows the graph of distribution of tasks by response type based on 'representation'. We can easily find more balanced distribution of tasks of different response types in the workbook than in KM1 and KM2

5. FINDING

We found significant results in the comparison of tasks according to cognitive expectation and response type. In the analysis of cognitive expectation, we found the following two features.

First, the workbook is well-balanced due to its distribution of cognitive expectation tasks. In the workbook, the number of tasks requiring concept knowledge and procedural knowledge increased whereas before, tasks requiring representation had composed a large portion of the tasks. Thus, there is a good balance of cognitive expectation tasks in the workbook, which we interpret as an improvement.

Second, the organization of the textbook reflects well the philosophy of the amendment. Tasks coding required consideration of a variety of cognitive aspects, for example, mathematical communication or mathematical deduction. Especially, in the textbook after the amendment, problems requiring discussion were added after each introductory section, and mathematical essay problems were provided at the end of each chapter. In the same context, the workbook contains tasks requiring step-by-step logical processes. These changes imply that the textbook after the amendment reflects the purpose of the amendment to improve students' ability in mathematical communication and problem solving through mathematical deduction, which is a positive outcome.

We found the following two features in the analysis of tasks by response type. First, the number of multiple-choice tasks increased; specifically, 1.1 type tasks increased dramatically. Students in Korea are required to solve problems of this type on midterms, finals, and the Korean SAT. Therefore, the workbook provides students practical help in preparing for the exams.

Second, the workbook is well-balanced in the sense of its distribution of tasks by problem type. The researchers scrutinized tasks for response type in each level of cognitive demand and found that the distribution of tasks by response type is well-balanced in each level of cognitive demand. This is a positive outcome because the workbook provides students with a variety of chances to write mathematical terminologies, notations, and formulas exactly. Also, by practicing these types of response tasks, students are expected to perform well on student assessments and exams.

The researchers paid attention to the relation among cognitive expectation, cognitive demand and response type. After much effort, we found two significant relations between cognitive expectation and cognitive demand.

First, there was a big difference in cognitive demand in tasks C and P. The textbook before the amendment had a similar distribution as the workbook. The next diagram illustrates the distribution of cognitive demand in tasks C and P.

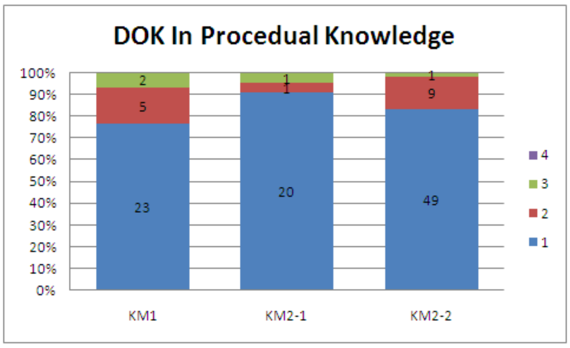

Figure 11. Percent of tasks according to DOK in PK

As shown in the diagram, the patterns of cognitive demand in C and P are very similar. There were no changes in the number of tasks in level 1, but the percentage increased from 62.5% (10 problems), 76.7% (11 problems) to 84.6% (23 problems), 90.9% (20 problems), respectively.

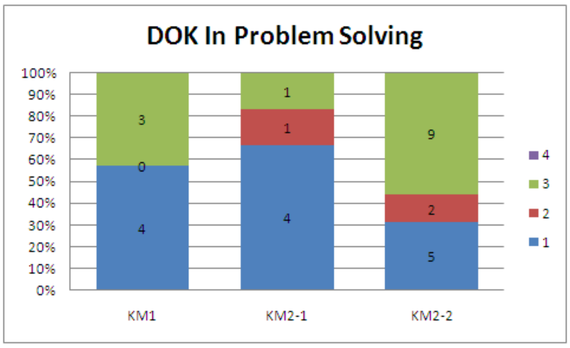

Figure 12. Percent of tasks according to DOK in PS

The distribution pattern of the workbook is very similar to the distribution pattern of the textbook before the amendment. Tasks requiring conceptual knowledge in the textbook after the amendment were adjusted to be easier than those in the textbook before the amendment, and tasks in the workbook preserve the level of difficulties.

Second, the distribution of cognitive demand according to PS had an obvious difference. The following diagram illustrates the distribution of cognitive demand according to

PS. In contrast, tasks of only levels 1 and 3 were provided in the textbook before the amendment, but the textbook after the amendment and workbook provided tasks in levels 1, 2, and 3. In particular, tasks in level 1 composed a significant portion of the tasks in the textbook before the amendment, and the workbook had more tasks in level 3.

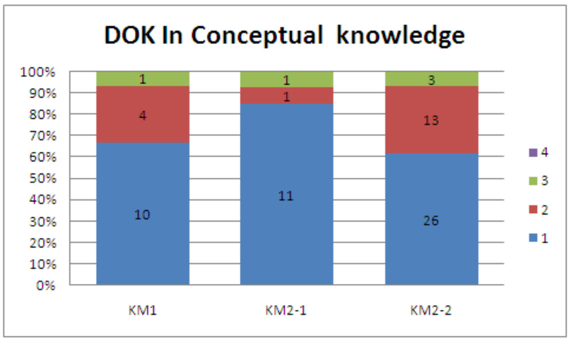

Figure 13. Percent of tasks according to DOK in CK

This implies that the textbook after the amendment has more variety and has been designed to be easier while the workbook has been designed to be more challenging. Considering all things, the textbook and the workbook divided their roles in the level of difficulty. In conclusion, the textbook after the amendment and the workbook provide students with the learning opportunity to solve the PS problems though a step-by-step process, which is regarded as a positive outcome.

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