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DEVELOPMENT OF IQP-BASED MATHEMATICS INSTRUCTIONAL QUALITY PROFILE

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Abstract. Mathematics education activities in schools are based on the mathematics curriculum. Mathematics education activities are carried out with mathematics instruction objectives, mathematics textbooks, and mathematics testing. In the present study, a new assessment tool, Mathematics Instructional Quality Profile (MIQP), was developed for the assessment of mathematics instructional quality on the basis of Instructional Quality Profile (IQP) used for assessing instructional quality with respect to the consistency and adequacy of instruction objectives, textbooks, and testing. The MIQP is anticipated to be used to collect basic information about the mathematics education activities performed in Korea to improve the mathematics curriculum, mathematics textbooks, and mathematics testing.

2010 Mathematics Subject Classification. 97C90, 97D30.

Keywords and phrases. Mathematics Instructional Quality Profile, Mathematics Curriculum, Mathematics Textbook, Mathematics Assessment.

1. Purpose and Need

Understanding of the mathematics education activities performed in the middle and high schools in Korea requires the accurate understanding of the mathematics curriculum, mathematics textbooks, and mathematics testing. The mathematics curriculum provides the features of mathematics, goals of mathematics subject, achievement criteria, instructional and learning methods, and testing methods ([21],[22]). The achievement criteria are reconstructed into lecture goals, which are used as references for the lecture activities performed at schools([31]). The Achievement Criteria Evaluation System has been implemented since 2014 academic year to perform education activities around the achievement criteria provided by the mathematics criteria ([14],[29]). Park et al.([13]) and Hwang et al.([6]) made sure through the revision study of mathematics curriculum that the achievement criteria should be accomplished through mathematics classes([1]) and the guidelines for textbook publishing also clarified that the achievement criteria are the references of mathematic textbooks. In this regard, the Ministry of Education and Human Resources Development([23])provided cautions in publishing textbook, forcing the observation of the achievement criteria through publishing of textbooks faithfully reflecting the curriculum, and establishment of levels and content adequate to the curriculum.

As described above, mathematics education activities at schools are performed within three major frames: achievement criteria provided by the mathematic curriculum, mathematics textbooks, and mathematics testing based on the achievement

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criteria. However, no studies have ever been conducted on the adequacy and consistency of the achievement criteria, mathematics textbooks, and mathematics testing in the mathematics curriculum. The studies for the development of the 2015 Revised Mathematics Curriculum emphasized the consistency in instruction, learning, and testing, while the term consistency is an exceptional word that has not been used even once in previous nine mathematics curricula. This reflected the self-recognition that the spirit of the curriculum is not actually applied to the testing situations in schools. The 2015 Revised Mathematics Curriculum([21])repeatedly emphasizes the consistency in principles of instruction and learning and principles of testing. This means that the attempts made in the past to improve mathematics education through the revision of curricula were not very much successful. In addition, this expresses the self-reflection about the lack of consistency between objectives, textbooks, and testing as well as the desire for specific realization in the future.

The National Curriculum for Mathematics is the foundation of mathematics education activities. The three cores elements of these education activities are achievement criteria, textbooks, and testing activities. Assessment of the consistency between the three components and the adequacy of individual components is a necessity for the success of mathematics education. Therefore, the purpose of the present study is to develop an assessment tool to evaluate the consistency and adequacy of the achievement criteria and textbooks provided by the curriculum and the problems used for regular exams at schools. To accomplish the purpose of the present study, the Instructional Quality Profile(IQP)for the assessment of the consistency and adequacy of objectives, textbooks, and testing was reviewed, and an assessment tool for the assessment of mathematics instructional quality profile was developed. The result of the present study may help to collect the basic information about mathematic education activities in Korea and provide significant implications about the development of achievement criteria, textbooks, and testing problems in the mathematics curriculum.

2. Theoretical Background

2.1. **Achievement criteria, Textbooks, and Testing in Mathematics Education**

2.1.1. *Achievement Criteria and Testing*

The need for establishing national achievement objectives to clearly describe the levels of national curriculum and education performance was raised from the 7th Mathematics Curriculum. The establishment of the national achievement goals have enabled school teachers to make concentrated efforts to accomplish the essential and minimum achievement goals, faithfully carrying out their education responsibilities. The national achievement goals have also enabled students to estimate their own level of accomplishment. The achievement criteria are the minimum standards of educational goals and the national reference of education([14],[29]). In addition, the achievement criteria are the minimum objectives that should be learned from school mathematics education at a national level as well as specific descriptions of the capabilities that students have to accomplish through the regular curriculum.

The significance of the achievement criteria is that they serve as the standards for school exams. The testing is performed by establishing achievement levels representing the degree of reaching achievement criteria for each subject, and the achievement

criteria provide guidelines for preparing problems for testing. Therefore, the mathematics testing problems are developed based solely on the achievement criteria provided by the mathematics curriculum.

2.1.2. *Textbooks*

The mathematics textbooks used in Korea include government-authorized textbooks and government-recognized textbooks. The core of development of the government-authorized or government-recognized textbooks is the textbook development directions provided by the 2015 Revised Mathematics Curriculum([13]). The textbook development directions are summarized into the following five points.

The first is the textbook development principles. The textbook development principles are divided into major principles and minor principles, and the major principles emphasize the consistency with the mathematics curriculum.

The second is the textbook structure framework. The structure framework provides guidelines about the composition and arrangement of chapters, balance between chapters, graded instruction and learning, and provision of chapter introduction.

The third is the textbook content selection. The content selection provides guidelines about the selection of content appropriate for fostering mathematics competence and the amount of content.

The fourth is the textbook content organization. The content organization gives an instruction that the content should be systematically organized by considering the connectivity between grades, between grade clusters, and between middle school and high school according to the learning hierarchy. In other words, the consistency with the curriculum is also emphasized in the content selection.

The fifth is the textbook development guidelines. The common textbook development guidelines state that the terms and signs provided by the mathematics curriculum should be defined and emphasizes the provision of tasks and activity materials to help students self-directed learning and various learning activities. This also emphasizes that mathematics textbooks should be prepared by thoroughly conforming to the mathematics curriculum.

2.2. **Instructional Quality Profile**

The Instructional Quality Profile(IQP)is a tool for assessing instructional quality. IQP is a result of the studies conducted mainly in the US about instructional quality where research was performed with respect to the generality utilization in content presentation form, the separation of content presentation form, variation of examples, and survey of content presentation form order([2],[4]). IQP was developed by Merrill and his colleagues([17],[20])as a result of a decade of research conducted to apply sciences to education by an academic collaboration with the US Ministry of Education. The research began with the anticipation that the principles of IQP will enable development of high-quality educational materials without trials and errors.

IQP is a tool of educational technology that evaluates the appropriate provision and implementation of the three individual curriculum components, which are objectives of instruction, presentation of instruction (textbooks and materials for instruction and learning), and test of instruction. Specifically, IQP enables the assessment of the consistency between the three components (educational objectives, textbooks, and testing) and the adequacy of the characteristics of the individual

components. IQP may also be used to examine, evaluate, and improve the overall curriculum as well as the efficiency of each component.

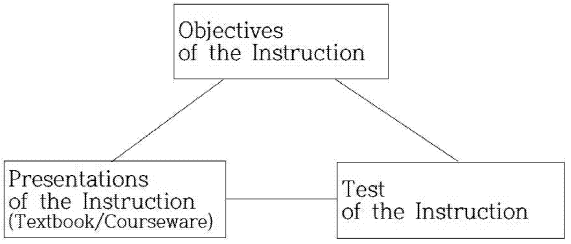

FIGURE 1. Relationship between components([33])

An ideal state of design and operation of the curriculum includes clearly described and specified purposes and objective of education. In addition, these purposes and objectives should provide guidelines for textbook publication and classroom lectures, and the basis for the relevant testing([18]). If sufficient information is provided with respect to the education objectives, instructional objectives, textbook content presentation, and testing, IQP may be divided into six sub-categories shown in Figure 2.

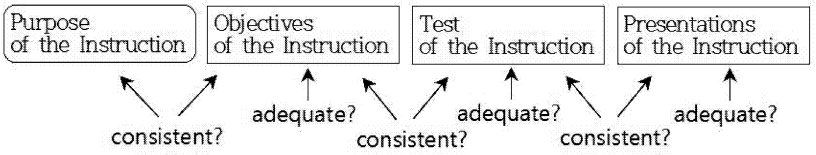

FIGURE 2. Six areas of instructional quality analyzed by IQP([33])

In Korea, IQP has been introduced as an assessment and analysis tool for instructional quality by the reports published by Na, Jung([15]), Jung, Na([10]), Choi([34],[35]), and Park, Choi([26]), and many implementation studies have been conducted. Examples of the IQP implementation studies include the study on the consistency and adequacy of middle school textbooks and objectives by Choi([9]), the IQP-based analysis of the learning content presentation forms in textbooks by Song([11]), and the component display theory(CDT)-based analysis of the consistency and adequacy of science content presentation by Beak et al.([27], [28]). In addition, Kim([8])reported that the academic achievement was significantly better in the group where IQP-based textbooks were used for learning, asserting that the currently used textbooks showed a consistency index of 0.62 and an adequacy index of 0.37. Choi([32])employed IQP as a tool to analyze chemistry textbooks and investigated the correlation between IQP index of chemical textbooks with the academic achievement found in the national standard academic achievement test, showing that more academic achievement was found in the group using textbooks having a higher IQP index. Shin, Seuel([7])analyzed the objectives of Korean language reading textbooks for the 5th and 6th graders of elementary schools as well as the class presentation forms. Seo([5])conducted a study on the consistency of the educational

objectives of the natural sciences subject for 3rd and 6th graders of elementary schools. Yeoun([36]) performed a comparative analysis of the English test problems between the University Entrance Test and the College Scholastic Ability Test to investigate the consistency of the instructional objectives and tests.

None of the studies have shown a result that violates or is opposite to the principle of the IQP theory, and most of the studies have shown that the IQP principles are right. The empirical studies showed that IQP is a very effective assessment tool. The IQP index has a value between 0.00 and 1.00 rounded off to three decimal places. A consistency index or an adequacy index closer to 1.00 is considered to represent appropriate instructional quality.

Although various studies have been conducted with regard to the IQP, the tool has two limitations. First, fragmentary studies have been conducted to analyze the consistency between the education objectives and textbooks, between textbooks and testing, and between testing and education objectives or to analyze the adequacy of the individual components, but almost no study has been conducted on the consistency among all the three components and the adequacy of all the three components. Only fragmentary studies have been conducted until now about the application of IQP because the analysis of the consistency among all the three components and the adequacy of all the three components is extensive and requires an assessment framework covering all the three component. The IQP tool has not been revised yet so that the characteristics of each subject may be taken into consideration. Second, no study has been conducted on the application of the IQP tool in the mathematics subject. Since the subject of mathematics is focused on the systematic teaching of the content and the education activities through problem-solving, less attention has been paid to the consistency among the curriculum objectives, textbooks, and test problems. However, the application of the IQP tool in the mathematics subject should be conducted because some students are currently giving up mathematics and social demand is being raised continuously for the revision of the mathematics curriculum.

3. Study Methods and Procedures

3.1. **Study Procedures**

A literature survey was conducted to assess the instructional quality in mathematics. On the basis of the literature survey, the basic components for Mathematics Instructional Quality Profile (MIQP) were identified. The MIQP was constituted with the basic components. The MIQP was revised and completed through a review by experts and an actual application to 8th graders.

3.2. **Collection and Analysis of Data**

3.2.1. *Study Assistants*

The appropriateness of the MIQP developed in the present study was validated through the collaborative study with three mathematics education experts and the consultation with one mathematics education expert and one mathematics expert. In addition, to improve the actual site appropriateness, the MIQP was reviewed by nine mathematics education experts who were school mathematics teachers.

3.2.2. *Study Subjects and Application*

Table 1. Research procedure

Step	Study content	Note
Literature Investigation	- Literature analysis for IQP -IQP literature analysis and analysis of IQP application examples in other subjects	Literature analysis
Development study	-Determination of MIQP components - Analysis of mathematics achievement criteria - Analysis of mathematics textbooks presentation forms, and analysis of test problems - Review by mathematics experts and mathematics education experts	Development of MIQP
Development of Final Version	-Determination of MIQP draft - First review and revision by school mathematics teachers - Application to 8th graders and revision - Final version of MIQP	Final version of MIQP

The basic framework of MIQP was developed on the basis of IQP. The three components of the MIQP were mathematics instruction objectives based on the achievement criteria, mathematics achievement testing based on regular school exams, and mathematics textbook content presentation based on mathematics textbooks. The sub-components were the consistency between mathematics instruction objectives and mathematics testing, the adequacy of mathematics testing, the consistency of mathematics testing and mathematics textbook content presentation, the adequacy of mathematics textbook content presentation, and the consistency between mathematics textbook content presentation and mathematics instruction objectives.

An actual application of the MIQP was performed to specify the MIQP on the basis of the selected components. The application was performed in five middle schools in Seoul, three middle schools in Daejeon, six middle schools in Daegu, and seven middle schools in Gyeongnam. The achievement criteria were firstly selected from the mathematics curriculum to determine the content type-task level, and then the textbooks for 8th graders were analyzed with problems in regular exams. Through these procedures, the MIQP components were finally determined.

3.2.3. *Collection and Analysis of Data*

To prepare the final version of MIQP, the MIQP draft was prepared in August, 2016, through periodic review of the MIQP with mathematics education experts. The draft was reviewed by mathematics education experts and mathematics experts to prepare the first revised version. A second revised version was prepared before the actual site application through the review by nine school mathematics teachers. An actual site application version was prepared through the discussion with the researchers. The final version of MIQP was prepared through two months of actual site application.

4. Results

4.1. **Method of Applying IQP to Mathematics Curriculum**

It is commonly regarded that the education objectives of mathematics are consistent with the instruction objectives. The consistency between the education objectives provided by the curriculum and the instruction objectives in classes may be verified from the configuration of the mathematics textbooks used in Korea. Hence, the development of MIQP is based on the analysis of the mathematics instruction objectives, mathematics testing, and mathematics textbook content presentation. The consistency and the adequacy of the mathematics instruction objectives, mathematics testing, and mathematics textbook content presentation may be analyzed on the basis of IQP within the triangular relationship (Figure 3).

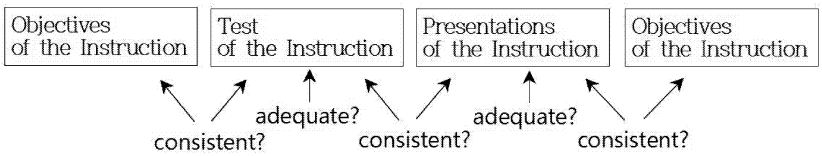

FIGURE 3. Five areas of instructional quality analyzed by MIQP

4.2. **Basis of MIQP Development**

4.2.1. *Task Level and Content Type*

Gagne, Briggs([24])one-dimensionally classified the types of learning results into verbal information, intellectual skills, cognitive strategies, motor skills and attitudes. Merrill([16]) developed the theory and two-dimensionally classified the type of learning results into task level and content type in a systematic way. First, the task level refers to a learners action level, which is related to the question, At what level should a student be able to utilize the things learned? The task level is divided into remembering, using, and finding. Remembering is an action to recall the information that has already been stored. Using is an action that requires an application of a general principle that has already been learned to a new example. Finding is an action that requires to derive or create novel abstractness. Second, the content type refers to the type of mathematics content, which is related to the question, 'What attributes does a mathematical object have?' The content type is divided into fact(FA), concept(CC), procedures(PD) and principle(PP). A fact refers to arbitrarily correlated fragments of information. For example, $f(x)$ is a sign of a function, and { }is a sign of a set. These are facts that are simple fragments of information. A concept refers to shared knowledge about objects, events, and signs having common characteristics and attributes. Examples of concent include the meaning of a function, the meaning of a null set, and the meaning of domain of definition. A procedure refers to the order of the steps needed to accomplish a certain goal, solve a specific problem, or to produce a product. Examples of procedure include a process of obtaining a solution by using the quadratic formula or a process of transforming $y = ax^2 + bx + c$ to $y = a(x - p)^2 + q$.

A principle refers to a cause-and-effect relation or a correlation that is used to interpret or understand an event or a phenomenon. The two-dimensional concepts of task level and content type in mathematics may be illustrated as a task level-content type classification table shown in Figure 4. In the present study, the classification

table was prepared on the basis of the achievement criteria for the 8th graders to develop the assessment tool.

Task level	Facts	Concepts	Procedures	Principles
Use of generalities				
Remember of generalities				
Remember of examples				

Content type

FIGURE 4. Combination of task level and content type

4.2.2. *Presentation Form*

Merrill, Boutwell([19])classified content presentation types into primary presentation form and secondary presentation form.

The primary presentation form is two-dimensional conceptualization of presented content and presentation mode. The presented content includes generality and instance. Generality, referring to a general statement of a concept, a procedure or a principle, may be presented as definition, stage, or law. An instance refers to a specific example of a concept, a procedure, and a principle. Presentation modes include explanation and question. The explanation refers to statement and interpretation, while the question refers to questioning where a learning content is presented in the form of a question or exemplifying where a learning content is presented in the form of an example.

		Presentation mode 'How is it presented?'	
		Explanation	Question
Instruction element 'What is presented?	Generality	Explanation via generality (E−Ge)	Question via generality (Q−Ge)
	Instance	Explanation via instance (E−In)	Question via instance (Q−In)

FIGURE 5. Primary presentation forms

According to IQP, the primary presentation form that should be presented to a learner is determined by the task level. Figure 6 shows the appropriate combinations of primary presentation forms for each task level. The X-shaped sections are the primary presentation forms that may not be included in each task level.

Second, the secondary presentation forms, mentioned by Merrill ([16]), were proposed to supplement the primary presentation forms, because the primary presentation forms were considered to be insufficient to express all the contents. According to Merrill et al.([17], [20]), all learning contents may exist in the primary presentation forms and the secondary presentation forms. The secondary presentation forms refer to the instructional quality adequacy profiles provided by the Instructional Strategy Diagnosis Profile(ISDP), such as context, preceding learning, memorization method, separation, help, feedback, pairing, and sampling.

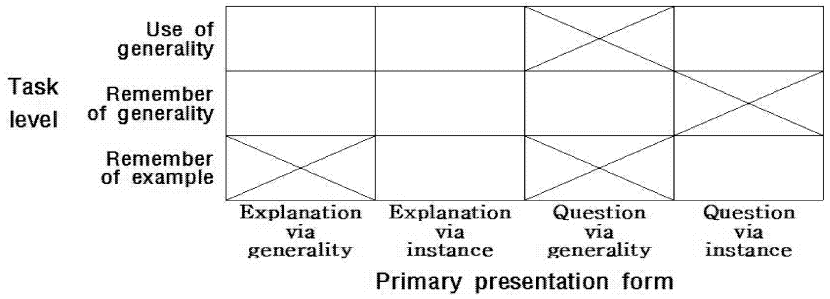

FIGURE 6. The Task-Primary presentation form matrix

4.3. **Development of MIQP**

4.3.1. *Direction of MIQP Development*

The most important part of MIQP development is the analysis of IQP, whose adequacy and validity have already been verified, and the analysis of previous studies. The adequacy and validity of IQP have already been verified by various studies, and MIQP was also developed on the basis of IQP.

4.3.2. *MIQP Development Procedures*

The MIQP development procedures are shown in Figure 7. The direction of the MIQP development was firstly determined. Then, the components of MIQP were selected through literature analysis. The final version of MIQP was prepared after undergoing appropriateness review and revision by experts.

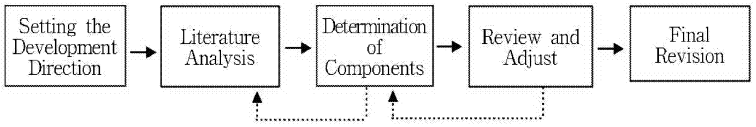

FIGURE 7. Procedures for the development of assessment tools

4.3.3. *Selection of MIQP Sub-Components*

The foundation of MIQP development is IQP. IQP consists of the six components shown in Figure 2. While IQP distinguished education objectives from instructional objectives, the education objectives provided by the curriculum are equal to the class objectives provided by the textbooks in the subject of mathematics. The instructional objectives of mathematics subject are based on the achievement criteria established by the state, and thus the adequacy is not a matter of assessment. Accordingly, the MIQP components were selected as shown in Figure 8. The MIQP sub-components were the consistency among the three components of mathematics instruction objectives (achievement criteria), mathematics textbook content presentation, mathematics testing (regular test problems) and the adequacy between the two components of mathematics textbook content presentation and mathematics testing.

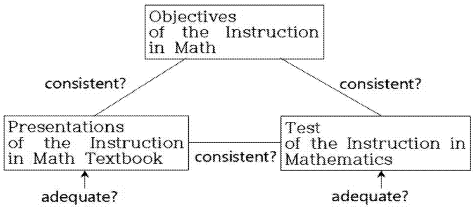

FIGURE 8. Relationship between components by MIQP

4.3.4. *MIQP Development*

To develop MIQP on the basis of the components and the sub-components, the criteria were determined as shown in Table 2. The assessment tool was developed by applying the criteria.

TABLE 2. Development Criteria for Assessment Tool

Item	Components	Criteria for MIQP development
Consistency	mathematics instruction objectives-mathematics textbooks	-Consistency between the task level-content types of two components - Combination of primary presentation forms and task level-content types
	Mathematics textbook-mathematics testing	- Consistency between the task level-content types of two components - Consistency between the number of different types and the number of problems presented
	Mathematics testing-mathematics instruction objectives	- Consistency between the task level-content types of two components - Consistency between achievement criteria and testing content elements
Adequacy	Mathematics textbook content presentation	- Combination of primary presentation forms and secondary presentation forms -Adequacy of textbook content presentation forms
	mathematics testing	- Adequacy with regard to accuracy, information and action, and problem set - Determination of appropriate number of problems and adequacy

4.3.5. *Review and Revision of MIQP*

Expert consultation was performed and review opinions were collected with regard to the developed MIQP. Table 3 summarizes the opinions for revision and the results of reflecting the opinions. 'Appendix A' shows the example remembering assessment tool finalized by reflecting the revision opinions. Described below shows the opinions about task level-content type and the results of reflecting the opinions.

a) Question about assessment tool(QA): Is the classification of content types and task levels appropriate? See Table 3.

b) QA: Six criteria have been presented for the problem adequacy assessment. Is it valid?

• Revision opinions(RO):
- Should the blanks be marked if there is no hint or feedback?
- Modifying the response level to a task level is appropriate.
- The agreement with curriculum should be included in the adequacy criteria.
- The adequacy criteria should be marked for each test problem. A single problem may not be assessed with respect to variability.
- The infallibility section may include accurate use of mathematical terms to accurately assess the content infallibility as well as the accuracy of terms or signs.

• Result of reflecting revision opinions(RR):
- The statement was revised to the hint in the problem sheet is not helpful.
- The expression was revised to curriculum agreement of task level.
- Curriculum agreement was added.
- The expression variability was revised to representativeness of objective accomplishment.
- The expression was revised to accuracy and infallibility.

c) QA: Is the secondary presentation form about example remembering valid?

• RO:
- I dont known what a non-example is.
- In the consistency section, if the blank is marked when there is one or more examples and if there is a example in the final sampling, should the both blanks for representativeness and variability be marked?

• RR:
- A non-example is something that is not a example. Additional explanation was provided.
- Two or more samples should be taken. The expression and means that both of the conditions should be met.

d) QA: Is the secondary presentation form appropriate for generality using?

•RO: In the adequacy criteria for the task level of generality using, the secondary presentation form question of the example question should be changed from the generality question to a example question.

•RR: The error was corrected.

e) QA: Is the calculation of the objective-testing consistency index or the testing adequacy index appropriate?

•RO:
- A subjective opinion may be reflected to the selection of the adequacy index for the number of problems.
- The adequacy index for the number of problems may be all different among the teachers. A reference may be prepared to determine the index value.
- Weight is given to the average in the calculation of assessment adequacy index. What determines the weight?

•RR:
- The assessment may be dependent on the expertise judgment of teachers.
- The calculation equation was modified by reflecting the opinion.
- The index was divided in to Index 1 and Index 2 to avoid the misunderstanding.

f) QA: Is the calculation of the testing-textbook content consistency index and the objective-textbook consistency index appropriate?
• RO: What determines the weight in the calculation of the testing-textbook content presentation consistency index?
• RR: The calculation result showed the presence of consistency. This does not indicates the consistency with textbooks. The current expression was maintained.

Table 3. Revised Version 2 of MIQP

No.	Content Type	RO	RR	Task level	RO	RR
M2-05	PD/PP	PD	PD	UG		
M2-09	PD	CC/PD	CC/PD	RG		
M2-13	PD	CC/PD	CC/PD	RG		
M3-19	PD	PP	PP	UG		
M4-23	PD	PP	PP	UG		
M5-24	PP			UG	UG/RG	UG/RG
M5-27	PP			UG	UG/RG	UG/RG
M5-30	PP			UG	UG/RG	UG/RG

4.4. **Final Version of MIQP**

4.4.1. *Consistency between Mathematics Instruction Objectives and Mathematics Testing*

No matter how well prepared the mathematics testing problems may be or however highly reliable the problems may be, the testing may not be appropriate if the direction of the testing problems is not consistent to the direction intended by the achievement criteria. To prevent such inconsistency, MIQP assesses and examines the consistency between the achievement criteria and testing problems. MIQP verifies if the problems included in the mid-term and final exams of first and second semesters are consistent with the achievement criteria provided by the mathematics curriculum. The verification of the consistency is performed through the procedures described below.

First, the mathematics achievement criteria are classified according to the task level-content type classification table(Appendix B). In the present study, the mathematics achievement criteria were finally determined through discussion with the researchers, first expert consultation, and second review reflecting mathematics teachers opinions. Second, the testing problems corresponding to the mathematics achievement criteria were found and classified according to the task level-content type classification table. Third, the consistency was reviewed between the task level-content type classification of the individual testing problems and the corresponding achievement criteria.

Fourth, it is verified if all the achievement criteria are presented in the mathematics testing problems. Fifth, the objective-testing consistency index is calculated. The index, calculated as (number of consistent problems)/(total number of problems), is entered. The total consistency index for all the problems is calculated as an average of the index values.

4.4.2. *Mathematics Testing Adequacy*

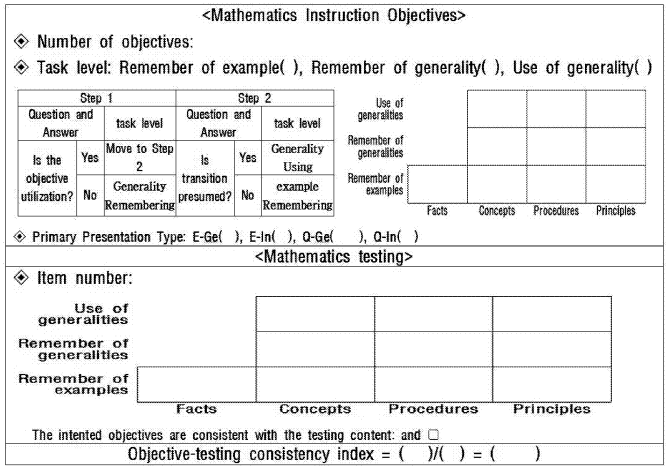

FIGURE 9. Objective-testing consistency assessment table

According to IQP, two kinds of features are involved in the review of the adequacy of testing adequacy: one is the features of provided information and required action, and the other is the features related with the sent of testing problems. Considering these features, the adequacy assessment using MIQP is performed through the following procedures([30]).

First, the technical accuracy of the individual testing problems is verified. Second, it is verified if the response level of each testing problem is optimal, if appropriate length of response time is given, and if the same testing sheet includes any hint or implication that may help to solve the problem. In other words, the adequacy of the information related to the testing problems and the actions required of the students is verified. Third, it is verified if the number of testing problems is adequate, if the variability and difficulty level for each objective are adequate, and if the problems agree to the adequate criteria for each objective. Fourth, the testing adequacy index is calculated. Two types of adequacy index are calculated. The testing adequacy index type 1 is an average of the adequacy index values of individual problems. The calculated adequacy index values of individual testing problems are averaged and recorded. In the present study, samples were taken from 21 schools in Korea, and four regular exams taken in the first and second semesters of 2015 were assessed with respect to the testing adequacy. The detailed elements of assesment determined through the application were the technical accuracy items, which are the readability of the testing problem statement, accurate use and infallibility of mathematical terms, curriculum agreement, task level agreement, absence of hint, representativeness (variability) of objective accomplishment, and difficulty. The testing adequacy index 2 is the adequacy index of the number of problems. The testing adequacy index 2 is one that is equal to or less than 1.0 of (number of problems)/(number of adequate problems) and (number of adequate problems)/(number of problems).

4.4.3. *Consistency between Mathematics Testing and Mathematics textbook content Presentation*

<Adequacy Assessment>

◈ Item number:

Adequacy criteria		Adequacy	Adequacy index
Accuracy	Readability of problem statement	▢	( )/7 = ( )
	Accuracy and infallibility	▢	
	Curriculum agreement	▢	
Information and action	Task level agreement	▢	
	Absence of hint or help in problem sheet	▢	
Problem set	Representativeness or variability of objective accomplishment	▢	
	Difficulty	▢	

Number of testing problems	Number of adequate problems	Adequacy index value of number of testing problems
( )	( )	( )

Testing adequacy index 1=[Average of adequacy index values of individual problems] = ( )
Testing adequacy index 2 = [Adequacy index of number of problems] = ( )

FIGURE 10. Testing adequacy assessment table

A testing problem listed in a test sheet may include the information needed for problem-solving neither in the textbook nor in the explanation provided by a teacher.

IQP helps to examine the adequacy of the instruction presentation form for each testing problem. In other words, IQP helps to check if appropriate information required for the testing is presented in the textbook. The testing-textbook consistency index is calculated through the following procedures.

First, the task level of each testing problem is verified with respect to each instructional objective. Second, the method of textbook content presentation to teach the students to reach the task level is examined. Third, it is verified if the textbook content presentation is efficient and economical. If the textbook content presentation has the task levels corresponding to the testing items, and if the textbook provides necessary information, the consistency between the testing and the textbook is recognized. The most important part of the verification and analysis of the testing-textbook consistency is the primary presentation form([19]). The combination of the primary presentation forms plays an important role in the analysis of the testing-textbook consistency. Fourth, the consistency index is calculated between the mathematics testing and the mathematics textbook content presentation. Two types of consistency index are calculated. The testing-textbook consistency index 1 is calculated as (number of problem consistent with textbook)/(total number of problems) and entered. The testing-textbook consistency index 2 is calculated as (number of problem types included in problem sheet)/(number of different problem types) and entered.

In the present study, the assessment was performed by writing the page numbers providing different contents provided in the textbook to learn the contents corresponding to the achievement criteria. In addition, the accurate number of primary presentation forms is investigated. For each content presentation, the task level and the primary presentation form are selected. The number of content presentation is entered into the corresponding blanks. If there is none, zero(0) is entered. The detailed task level-primary presentation classification table may be used to verify the consistency with a testing problem. The number of corresponding content presentation is entered into each blank.

4.4.4. *Adequacy of Mathematics Textbook Content Presentation*

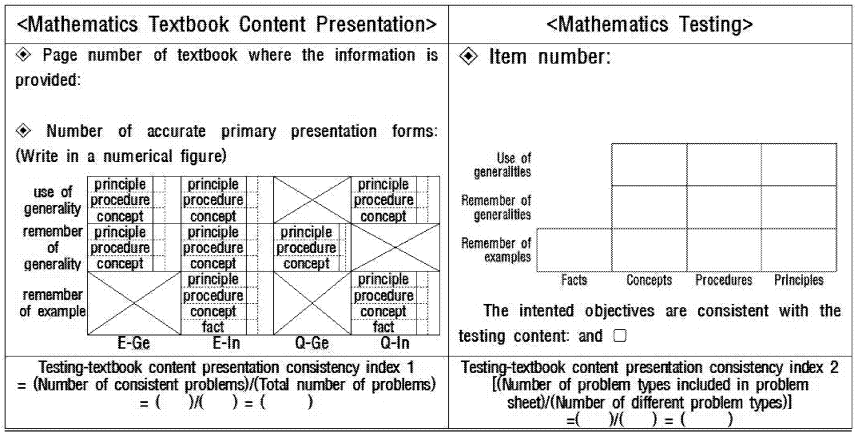

FIGURE 11. Testing-textbook consistency assessment table

IQP examines and assesses if the instructional presentation is brief and easy to efficiently reach appropriate task levels, adequately explained, and sufficiently specified. This process examines and assesses if the individual components of primary presentation forms accompany adequate secondary presentation forms and if the strategical elements and feature needed to reach adequate take levels are presented. The textbook content presentation adequacy is assessed in MIQP through the following procedures.

First, it is verified if the strategical elements needed for each primary presentation type is actually included in the content presentation. Second, it is verified if the individual strategical elements are actually equipped with the needed features. Third, the adequacy index of mathematics textbook content presentation is calculated as (number of problems)/(total number of problems).

In the present study, the items in the textbook adequacy assessment table included example remembering, generality remembering, and generality using for each task level. Figure 12 show the adequacy criteria assessment table with respect to example remembering and generality remembering.

The 'non-example' in the assessment tables means what is not an example and is different from a counter-example. For instance, $1/2$ is an example of rational number, but $\sqrt{2}$ is a non-example of rational number.

4.4.5. *Consistency between Mathematics Textbook Content Presentation and Mathematics Instruction Objectives*

The consistency between instructional objectives and mathematics textbooks is analyzed through the following procedures on the basis of IQP analysis. First, the task levels of the educational objects are classified. Second, the primary presentation types needed for the classified task levels are verified. Third, it is verified if the primary presentation types adequate to the task level of each objective are provided in the textbook. Necessary primary presentation types and unnecessary primary presentation types are identified. Fourth, the completeness of the individual primary presentation types provided in the textbook is analyzed. Fifth, the consistency

<example remembering adequacy criteria>			
1. Example explanation		Assessment	Index
Consistency: Are there one or more explanations about a example?			☐
Separation	Are the example explanations separated?		and ☐
	Is there a mark for "example"?		
Help	Is a help accompanied?		or ☐
	Dose at least one example explanation employ a simplified symbol?		
Pairing	Do most examples accompany a non-example?		☐
Sampling	Do the examples represent the difficulty population?		and ☐
	Do the features of the examples have variability?		
example explanation index			( )/5
2. Example questioning		Assessment	Index
consistency: Are one or more example questions provided?			☐
Separation	Are the example questions separated?		and ☐
	Is there a mark for "example question"?		
	Are the feedback presentations separated?		
	Is there a mark for "feedback presentation"?		
Help	Is a hint excluded from the example question?		or ☐
	Is a help provided for feedback presentation?		
Pairing	Are the example questions randomly arranged by pairing?		☐
Sampling	Do the features of the exercise problems have variability?		and ☐
	Has the difficulty level been considered?		
example question index			( )/5
Total index			( )/10

<Generality remembering adequacy criteria>			
1. Generality explanation		Assessment	Index
consistency: Are there one or more explanations about generality?			☐
Separation	Are the generality explanations separated?		and ☐
	Is there a mark for "generality"?		
Help	Are various forms of symbols used?		or ☐
	Is a remembering help provided?		
Generality explanation index			( )/3
2. example explanation		Assessment	Index
consistency: Are there one or more explanations about a example?			☐
Separation	Are the example explanations separated?		and ☐
	Is there a mark for "example"?		
Help	Is a help accompanied?		or ☐
	Dose at least one example explanation employ a simplified symbol?		
example explanation index			( )/3
3. Generality questioning		Assessment	Index
consistency: Are one or more generality questions provided?			☐
Separation	Are the generality questions separated?		and ☐
	Is there a mark for "generality question"?		
	Are the feedback presentations separated?		
	Is there a mark for "feedback presentation"?		
Help	Is a hint excluded from the generality question?		and ☐
	Is a help provided for feedback presentation?		
Generality question index			( )/3
Total index			( )/9

Figure 12. Adequacy assessment table

index between the textbook content presentation and the instructional objectives is calculated as (number of provided primary presentation forms)/(number of primary presentation types applicable to the task level).

5. Conclusions and Recommendations

The purpose of the present study is to develop an MIQP to assess the consistency between the three cores elements of mathematics education activities, which are achievement criteria, textbooks, and testing activities, as well as the adequacy of the three individual elements. The conclusions drown from the results earned from the present are as follows.

First, a literature survey was conducted as a fundamental analysis for the development of MIQP. The survey showed that IQP is based on task levels and content types and that primary presentation forms and secondary presentation forms are utilized as important tools for the consistency and adequacy analysis. Second, the components and sub-components for the MIQP development were selected. The selected MIQP components were the achievement criteria, which are the mathematics

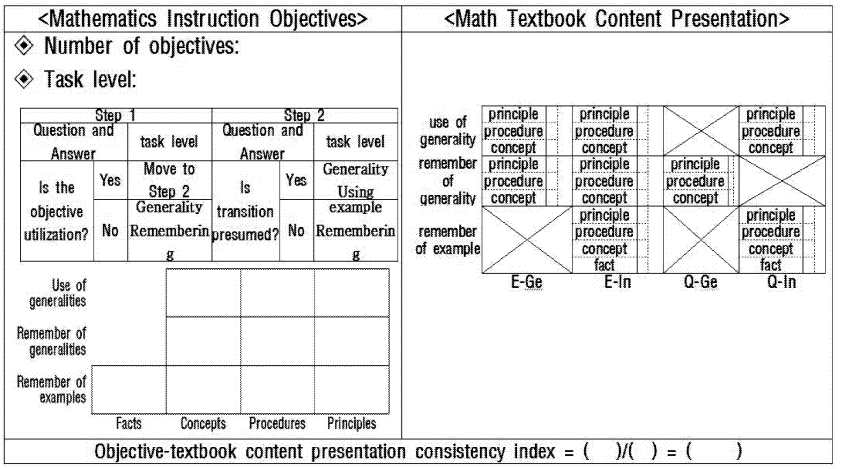

FIGURE 13. Objective-textbook consistency index assessment table

instructional objectives provided by the curriculum, mathematics textbooks content presentation, and mathematics testing. The sub-components were the consistency between mathematics instruction objectives and mathematics textbook content presentation, the consistency between mathematics textbook content presentation and mathematics testing, the adequacy of mathematics textbook content presentation, and the adequacy of mathematics testing. Third, a specific assessment tool was developed to calculate the consistency index and the adequacy index. Relevant criteria for the assessment tool development were also established, and an MIQP was developed on the basis of the criteria. Fourth, the applicability of the developed MIQP was verified by applying it to 8th graders. The final version of MIQP was prepared on the basis of the application.

The MIQP developed in the present study may help to collect the basic information about mathematic education activities in Korea and provide significant implications about the development of achievement criteria, textbooks, and testing problems in the mathematics curriculum. Additionally, the following recommendations are provided.

First, the MIQP developed in the present study may be used to examine the mathematics education activities performed at the middle and high schools in Korea. This will enable the review of the consistency between the achievement criteria provided by the mathematics curriculum and the mathematics textbooks. In addition, the MIQP may be used to collect specific information about the consistency between the mathematics testing and the mathematics textbooks used in classrooms. Second, the MIQP may be used to compare the mathematics education activities of the past and the present, because the mathematics education activities have not been significantly improved even by the ten times of revision of the mathematics curriculum. Third, the MIQP may be used to collect the basic information about the argument that the excessive amount of contents included in the mathematics curriculum may be one of the factors causing some students to give up the study of mathematics. Fourth, the MIQP may be used as a basic tool to analyze the

difficulty level of mathematics textbooks, school exams, and the College Scholastic Ability Test. Fifth, the MIQP may be used to analyze the consistency between the university entrance tests and the mathematics textbooks of three neighboring countries, including Japan, China, and Russia, to collect useful information needed to improve Koreas mathematics education.

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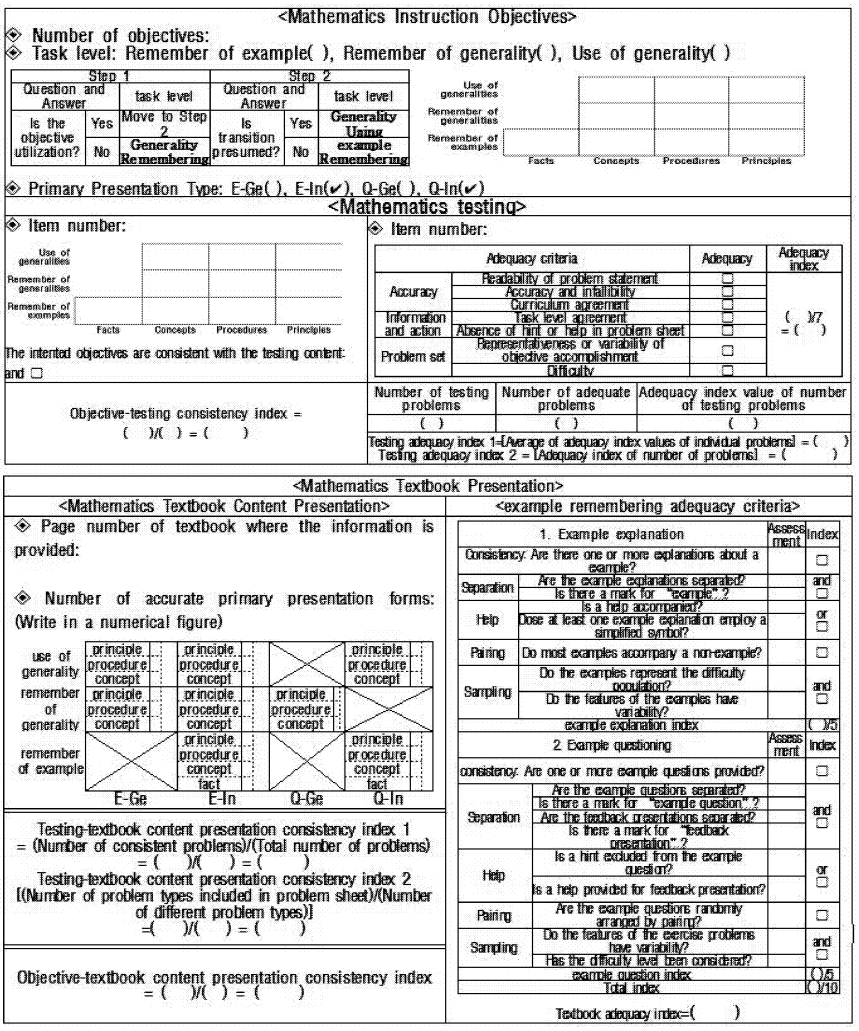
Appendix A. MIQP Assessment Tool for Case 'Remember of Instance'



<Mathematics Instruction Objectives>

◈ Number of objectives:

◈ Task level: Remember of example( ), Remember of generality( ), Use of generality( )

Step 1			Step 2		
Question and Answer		task level	Question and Answer		task level
Is the objective utilization?	Yes	Move to Step 2	Is transition presumed?	Yes	Generality Using example
	No	Generality Remembering		No	Remembering

	Facts	Concepts	Procedures	Principles
Use of generalities				
Remember of generalities				
Remember of examples				

◈ Primary Presentation Type: E-Ge( ), E-In(✔), Q-Ge( ), Q-In(✔)

<Mathematics testing>

◈ Item number:

	Facts	Concepts	Procedures	Principles
Use of generalities				
Remember of generalities				
Remember of examples				

The intented objectives are consistent with the testing content: and ☐

Objective-testing consistency index = ( )/( ) = ( )

◈ Item number:

Adequacy criteria		Adequacy	Adequacy index
Accuracy	Readability of problem statement	☐	( )/7 = ( )
	Accuracy and infallibility	☐	
	Curriculum agreement	☐	
Information and action	Task level agreement	☐	
	Absence of hint or help in problem sheet	☐	
Problem set	Representativeness or variability of objective accomplishment	☐	
	Difficulty	☐	

Number of testing problems	Number of adequate problems	Adequacy index value of number of testing problems
( )	( )	( )

Testing adequacy index 1=[Average of adequacy index values of individual problems] = ( )

Testing adequacy index 2 = [Adequacy index of number of problems] = ( )

<Mathematics Textbook Presentation>

<Mathematics Textbook Content Presentation>

◈ Page number of textbook where the information is provided:

◈ Number of accurate primary presentation forms: (Write in a numerical figure)

	E-Ge	E-In	Q-Ge	Q-In
use of generality	principle, procedure, concept	principle, procedure, concept		principle, procedure, concept
remember of generality	principle, procedure, concept	principle, procedure, concept	principle, procedure, concept	
remember of example		principle, procedure, concept, fact		principle, procedure, concept, fact

Testing-textbook content presentation consistency index 1 = (Number of consistent problems)/(Total number of problems) = ( )/( ) = ( )

Testing-textbook content presentation consistency index 2 [(Number of problem types included in problem sheet)/(Number of different problem types)] =( )/( ) = ( )

Objective-textbook content presentation consistency index = ( )/( ) = ( )

<example remembering adequacy criteria>

1. Example explanation		Assessment	Index
Consistency: Are there one or more explanations about a example?			☐
Separation	Are the example explanations separated?		and ☐
	Is there a mark for "example"?		
Help	Is a help accompanied?		or ☐
	Dose at least one example explanation employ a simplified symbol?		
Pairing	Do most examples accompany a non-example?		☐
Sampling	Do the examples represent the difficulty population?		and ☐
	Do the features of the examples have variability?		
example explanation index			( )/5

2. Example questioning		Assessment	Index
consistency: Are one or more example questions provided?			☐
Separation	Are the example questions separated?		and ☐
	Is there a mark for "example question"?		
	Are the feedback presentations separated?		
	Is there a mark for "feedback presentation"?		
Help	Is a hint excluded from the example question?		or ☐
	Is a help provided for feedback presentation?		
Pairing	Are the example questions randomly arranged by pairing?		☐
Sampling	Do the features of the exercise problems have variability?		and ☐
	Has the difficulty level been considered?		
example question index			( )/5
Total index			( )/10

Textbook adequacy index=( )

FIGURE 14. MIQP Assessment Tool for Case 'Remember of Instance'

Appendix B. Task level-content type classification table for 8th graders in 2009 Reformed Mathematics Curriculum

Table 4. Task level-content type classification table

Mathematics instruction objectives (Achievement criteria)	Type	Level
To understand the meaning of recurring decimals	CC	RG
To understand the correlation between rational numbers and recurring decimals	PP	RG
To understand exponential law	PP	RG
To understand the principle of quadratic polynomial addition and subtraction and carry out the calculation	PD	RG
To understand the principle of polynomial multiplication and derive formulas of multiplication	PD	UG
To understand the principle of polynomial division and carry out the calculation	PD	RG
To transform simple equations	PD	RG
To understand the meaning of linear equations with two unknowns and their solutions	CC	RI/ RG
To understand the meaning of simultaneous linear equations with two unknowns and their solutions and solve them	CC/ PD	RG
To apply simultaneous linear equations with two unknowns to solve various problems found in daily living	PP	UG
To understand the meaning of linear inequality and their solutions by using various situations	CC	RI/ RG
To apply the basic characteristics of inequality to solve linear inequality	PD	RG
To understand the meaning of simultaneous linear inequalities and their solutions and solve them	CC/ PD	RG
To apply a linear inequality or simultaneous linear inequalities to solve various problems found in daily living	PP	UG
To understand the meaning of linear function and plot it	CC	RI/ RG
To understand the characteristics of a plot of a linear function	CC	RG
To apply linear function to solve various problems	PP	UG
To understand the correlation between linear function and simultaneous linear equations with two unknowns	PP	RG
To understand the solutions of simultaneous linear equations through the plots of two linear functions	PP	UG
To calculate number of cases	CC/ PP	RI
To understand the meaning of probability	CC	RG
To understand the basic characteristics of probability	PP	RG

Table 4. Continued

Mathematics instruction objectives (Achievement criteria)	Type	Level
To calculate probability	PP	UG
To understand and explain the characteristics of isosceles triangle	PP	RG UG
To understand and explain the congruence conditions of right-angled triangles	PP	UG
To understand and explain the characteristics of the incenter and the circumcenter of a triangle	PP	UG
To understand and explain the characteristics of a parallelogram	PP	RG/ UG
To understand and explain the characteristics of various types of quadrangles	PP	UG
To understand the meaning of similarity of figures	CC	RI
To understand the characteristics of similar figures	PP	RG/ UG
To understand the conditions of similarity of triangles and use it to determine similarity of two triangles	CC	RG
To calculate the ratio of segment length between two parallel lines	PP	UG
To understand the characteristics of a segment connecting two median points of two sides of a triangle and the meaning of center of mass	PP	UG
To apply the characteristics of similar figures to solve various problems	PP	UG

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