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This article has been retracted at the request of the author.

After publication, the author informed the Publisher that the article included work derived from a graduate student's thesis research. Under institutional research ethics regulations, the graduate student should have been listed as a co-author. Because the authorship record cannot be corrected post-publication in a way that meets those requirements, the author requested retraction of the article.

There is no evidence of data fabrication, plagiarism, or duplicate publication associated with this article. The retraction is issued solely to correct the authorship record and to comply with research ethics requirements.

APPLICATION OF INQUIRY-BASED SCIENCE ASSESSMENT QUESTIONS FOR KOREAN ELEMENTARY STUDENTS (II)

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Abstract

This study aims to incorporate inquiry-based assessment questions in science assessment and analyzes students' responses in purpose of evaluating scientific inquiry abilities of fifth and sixth grade students in Korea. In this study, we mainly report the result about matter (chemistry) content domain among assessment questions. The results were as follows. First, scientific inquiry abilities of fifth and sixth graders in Korea elementary school are lower than that of their general school's assessment. Second, students' preconception and misconceptions in matter content domain were obtained through the development and application of inquiry-based assessment questions, and teaching approaches for increasing students' inquiry skills were also obtained.

Key words: *Inquiry based assessment, Elementary student, Inquiry ability, Korea, Matter domain*

1. INTRODUCTION

1.1. Research aim and motivation

Many nations in the world today believe that science and technology are the keys in leading the national competitiveness in the future (MEST 2012, MEST 2011, NRC, 1996). And Science and technology often act as an indicator of a nation's future (MEST 2010, Koh 1994), and many countries including Korea constantly thrive to bring up their educational process to the world-class level through comparison studies on education achievement across the world such as TIMSS (Trends in International Mathematics and Science Study) and PISA (The Programme for International Student Assessment) survey (Martin 2004, Martin 2008, OECD 2010).

There had been many studies on analyzing scientific education achievements using questions from TIMSS and PISA survey and applying the results to the academic curriculum in Korea (Soo 2007, Kong 2011, Kim 2009, Lee 2011, Ju 2010, Hong 2006), but there had rarely been a study based on the inquiry learning elements suggested by the current national science curriculum.

In science education, it is most ideal for students to understand scientific concept and develop knowledge from inquiry skills gained through inquiry activities (Lee 2007, NRC 2000, Abd-El-Khalick 1998, Akerson 2007). Therefore, performance assessment in science needs to transcend the conventional method of each question asking for an independent set of idea and concepts. It should develop students' inquiry skills during the assessment by fluidly linking questions with each other within the assessment through inquiry activities. For this purpose, a performance assessment emulating scientists' inquiry activities in set of several inquiry stages needs to be developed (Koh 1994, Lee 2007, Kwon 1994, Song 2004, Shin 1998, Woo 1998, Lee 2011).

This study devises inquiry-based science assessment questions based on the NAAA (National Assessment of Academic Ability) developed by NIER (National Institute for Educational Policy Research of Japan) to test inquiry skills of fifth and sixth graders in Korea in order to find a method of assessment that can heighten students' inquiry abilities. Furthermore, the study analyzes percentage of correct answers and commonly chosen wrong answers to propose guidelines on building inquiry-based science questions. This study also provides different teaching approaches for building students' inquiry skills by gathering students' preconceptions and misconceptions on science from each question.

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1.2 Research problem

The research tasks are as followed. First, we develop inquiry-based science assessment questions on matter (chemistry) content domain for elementary students. Second, we analyze percentage of correct answers on the devised questions. Third, we analyze commonly chosen wrong answers on the devised questions.

1.3 Research limitations

First, the chosen research subjects were limited to fifth and sixth graders from seven elementary schools in Woolsan and Gyeongsangnam-do, Korea.

Second, the structure of assessment categorized inquiry skills and subject of each question based on the currently enforced 2007 amendment of national science curriculum of Korea.

Third, the assessment is made of questions in subject areas of kinetics & energy, matter, biology, earth & universe, and there were also questions that ask for students' basic scientific knowledge and concepts as part of the inquiry process.

2. RESEARCH METHODS

2.1. Research subjects and period

The research subjects selected for this study were 1,198 students, of who are 421 fifth graders and 777 sixth graders from seven elementary schools in Changwon, Jinju, Sacheon, Tongyeong, Hamyang, and Woolsan in the Province of Gyeongsamnam-do.

The assessment was carried out and collected over two weeks period starting in mid-April 2013. The aim of the assessment, the rules and guidelines on the assessment were delivered to teachers before the assessment. The assessment time was set to 40 minutes.

2.2. Assessment

The assessment used for this research was made by modifying and reinforcing the NAAA (National Assessment of Academic Ability) developed by NIER (National Institute for Educational Policy Research of Japan) accordingly to the level of 2007 amendment of science education curriculum of Korea. The assessment is made of four questions in matter domain. The assessment questions were first translated by a researcher and modified, and then reviewed by two elementary teachers.

Each question has elements of fundamental inquiry skills and comprehensive inquiry skills, and questions were developed considering the connections between different questions to measure students' inquiry skills through inquiry activities. Question types were multiple choices, short answers, short essays, or combined answer (multiple choice + short answer or short essay). Inquiry types and functions of each question are as listed in table 1.

Table 1. Framework for inquiry skill and inquiry function for 'matter' domain

Question No	Inquiry subject	Inquiry type	Inquiry function
1	States of matter and change in mass	Fundamental	Measurement
2	Mass before and after dissolution	Fundamental	Measurement
3	Solution properties	Comprehensive	Data analysis, Conclusion
4	Solution properties	Comprehensive	Generalization

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2.3. Response analysis

The answers were graded using a prepared rubric in order to minimize subjectivity of the grader. Partially correct answer, wrong answer, and no response were all handled accordingly and separately as necessary.

Of the research subjects of fifth and sixth graders, sixth graders' percentage of correct answers and commonly chosen wrong answers on question materials covered in the fifth grade curriculum were used to analyze possible misconceptions. Both fifth and sixth graders' responses to questions not covered by the standard curriculum were used to analyze any preconception held by students. The overall percent correct as well as the percent correct by class year and gender were also compared in order to analyze amount of understanding and amount of achievement on the assessment in different groups.

The questions were analyzed using the following criteria. First, what is the asked inquiry function in the question? Second, what is being inquired in the question? Third, how does this question's percent correct compare to the overall percent correct? Fourth, what is the percent correct by students' class year? Fifth, what is the percent correct by students' gender? Sixth, what is the most commonly chosen wrong answer, and why? Seventh, what are students' preconceptions and misconceptions that can be learned from commonly chosen wrong answers?

3. RESULTS AND ANALYSIS

3.1 Percentage of correct answers

3.1.1 Overall percent correct

The percentages of correct answers to inquiry-based science assessment questions were analyzed by question type and material as in table 2. Overall percentage of correct answers on the assessment in matter domain was 52.60%. The percent correct of inquiry-based assessment questions were lower than that of the general schools' assessment.

Table 2. Percentages of correct answers to inquiry-based assessment questions (%)

	Sexual correction (%)				Year corrections(%)		
	Girl (N=559)		Boy (N=639)		5th grade	6th grade	Total (N=1198)
	5th grade	6th grade	5th grade	6th grade			
Matter	39.60	59.58	43.58	57.65	41.67	58.55	52.60
	52.24		52.94				

3.1.2 Percent correct by class year

Percent correct per class year was 16.88% higher for 58.55% in sixth grade than 41.67% in fifth grade.

3.1.3 Percent correct by gender

Overall inquiry skills appeared slightly superior in boys who scored 52.94% compared to girls who scored 52.24%.

3.2 Relevance to the academic curriculum

The percentages of correct answers to inquiry-based assessment questions by material coverage of currently enforced 2007 amendment of science education curriculum are organized as in table 3. Of the 4 assessment questions, 1 question (25%) were covered in fifth grade curriculum and 4 questions (100%) were covered in sixth grade curriculum.

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Table 3. Course coverage for questions for matter domain

Question	2007 amendment of science education curriculum			
	Related class year and chapter*	Covered material	Course coverage	
			5th grade	6th grade
Q1. States of matter and change in mass	3-1-1. Matter in our daily life	- Properties of solid - Properties of powder	Covered	Covered
Q2. Change in mass before and after dissolving	5-2-2. Solutions and dissolving	- Solubility of a solid against solvents - Mass change before and after dissolving	Not covered	Covered
Q3. Solution properties	5-2-2. Solutions and dissolving	- Basic concepts of solutions and dissolving	Not covered	Covered
Q4. Solution properties	5-2-2. Solutions and dissolving	- Basic concepts of solutions and dissolving	Not covered	Covered

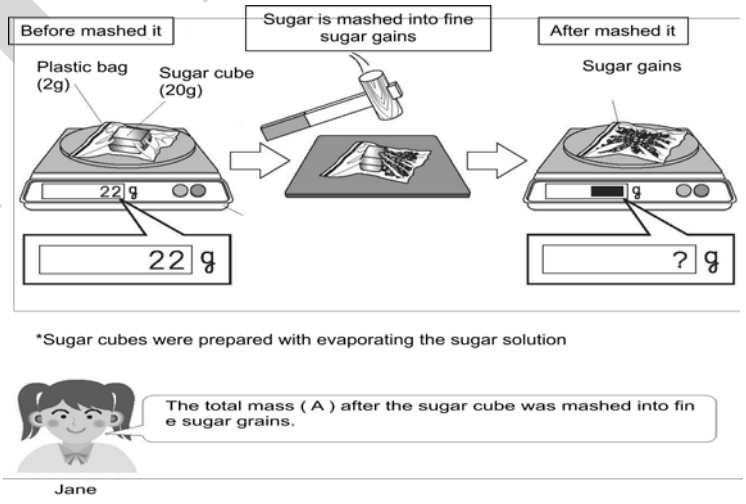
*3-1-1 means that 3rd year, 1st chapter and 1st unit.

3.3 Analysis per question

Each assessment question was further examined for its percent correct and for its commonly chosen wrong answer based on the particular inquiry skill demanded by the question. First, the particular inquiry skill asked by each question is described, and then student responses are listed in tables. The percent correct and wrong answers on each question are then analyzed to quarry for possible preconceptions and misconceptions students have on each question.

3.3.1 Question 1. States of matter and change in mass

Question 1. A sugar cube and a plastic bag are weighed to be 22 g (grams) total as illustrated in the figure below. The sugar cube is then mashed into fine sugar grains for better solubility, and then the crushed sugar grains and plastic bag are weighed together.



Please complete the sentence by filling (A) with one of the following choices. Mark the correct

answer choice number in your answer sheet.

① Becomes lighter than 22g (grams)

② Does not change from 22g (grams)

③ Becomes heavier than 22g (grams)

④ Becomes equal to the mass of the plastic bag

Table 4. Percent correct on question 1 by class year

Year	Responded type	Question 1						Total
		0	1	2	3	4	9	
5th	Probability	1	108	287	14	8	3	421
	%	.2	25.7	68.2	3.3	1.9	.7	100.0
6th	Probability	1	69	679	14	3	11	777
	%	.1	8.9	87.4	1.8	.4	1.4	100.0
Total	Probability	2	177	966	28	11	14	1198
	%	.2	14.8	80.6	2.3	.9	1.2	100.0

Table 5. Percent correct on question 1 by gender

Year	Sex	Responded type	Question 1						Total
			0	1	2	3	4	9	
5th	Girl	Probability	0	56	139	10	2	0	207
		%	.0	27.1	67.1	4.8	1.0	.0	100.0
	Boy	Probability	1	52	148	4	6	3	214
		%	.5	24.3	69.2	1.9	2.8	1.4	100.0
6th	Girl	Probability	0	34	312	4	1	1	352
		%	.0	9.7	88.6	1.1	.3	.3	100.0
	Boy	Probability	1	35	367	10	2	10	425
		%	.2	8.2	86.4	2.4	.5	2.4	100.0

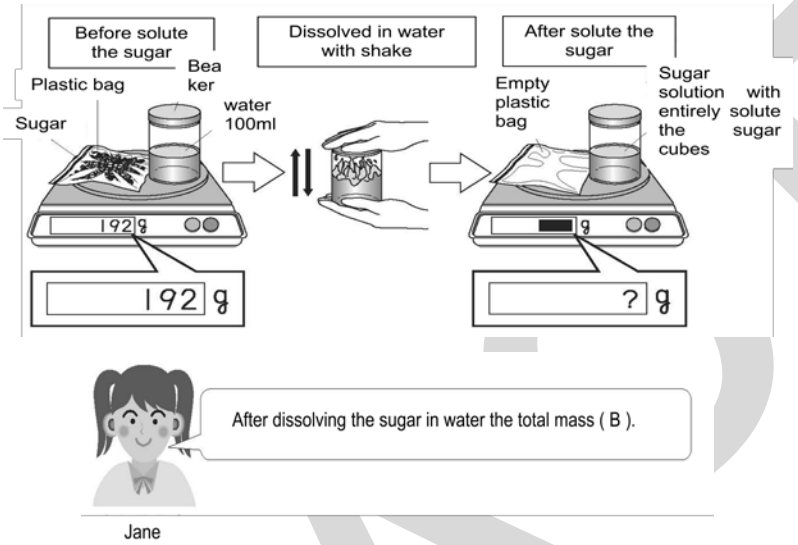
The inquiry skill imposed by this question is “measurement”, which is one of the fundamental inquiry skills, and the question tests for student’s ability to perceive conservation of mass when state of matter changes by comparing the mass of a sugar cube before and after it is crushed into grains.

This question was answered correctly by 80.6% of the test-takers, which is a higher value than the overall percentage of correct answers(Kong 2014). The sixth graders showed higher percent correct than fifth graders, and this shows that elapsed time since material coverage do not have strong correlation with the associated inquiry skill since the topic on solid properties and particle properties is covered during third grade. As for gender variation, boys had higher percent correct in fifth grade, and girls had higher percent correct in sixth grade.

Answer choice ① was the most commonly selected wrong answer, chosen by 14.8% of test-takers. This was likely caused by a misconception held by students that mass would decrease when going from solid chunk to finer particles since visible volume of matter decreases. This shows that a large number of fifth graders do not yet understand the concept of conservation of mass.

3.3.2 Question 2. Change in mass before and after dissolving

Question 2. The crushed sugar particles in question 1 and a beaker containing 100 ml (milliliters) of water were weighed to be 192 g (grams) total as in the figure below. The sugar particles were then dissolved in water by stirring, and the total mass of the solution was weighed again.



Please complete the sentence by filling (B) with one of the following choices. Mark the correct answer choice number in your answer sheet.

① Becomes lighter than 192 g (grams).

② Does not change from 192 g (grams).

③ Becomes heavier than 192 g (grams).

④ Becomes equal to the total mass of the plastic bag, beaker, and 100 ml (milliliters) of water.

Table 6. Percentage of correct answers on question 2 by class year

Year	Responded type	Question 2						Total
		0	1	2	3	4	9	
5th	Probability	1	124	201	65	27	3	421
	%	.2	29.5	47.7	15.4	6.4	.7	100.0
6th	Probability	3	68	629	42	24	11	777
	%	.4	8.8	81.0	5.4	3.1	1.4	100.0
Total	Probability	4	192	830	107	51	14	1198
	%	.3	16.0	69.3	8.9	4.3	1.2	100.0

Table 7. Percentage of correct answers on question 2 by gender

Year	Sex	Responded type	Question 2 0	1	2	3	4	9	Total
5th	Girl	Probability	0	65	92	33	17	0	207
		%	.0	31.4	44.4	15.9	8.2	.0	100.0
	Boy	Probability	1	59	109	32	10	3	214
		%	.5	27.6	50.9	15.0	4.7	1.4	100.0
6th	Girl	Probability	1	29	297	12	12	1	352
		%	.3	8.2	84.4	3.4	3.4	.3	100.0
	Boy	Probability	2	39	332	30	12	10	425
		%	.5	9.2	78.1	7.1	2.8	2.4	100.0

The inquiry skill imposed by this question is “measurement”, which is one of the fundamental inquiry skills, and the question tests for student’s understanding of conservation of mass during dissolving by comparing the mass of a solution before and after dissolving a sugar cube in a solution.The percent correct on this question was 69.3%, which was higher than the overall percent correct.

The percent correct of sixth graders were almost twice as higher than that of fifth graders, and this is probably because the material regarding this particular question was covered in the sixth grade curriculum but not in the fifth grade curriculum.

As for gender variation, boys scored higher in fifth grade, and girls scored higher in sixth grade.

Most students picked answer choice ①, “Becomes lighter”, as the wrong answer, because students would associate sugar’s visible disappearance from dissolving as non-existential state of matter and cannot grasp the concept of sugar coexisting invisibly within the water.

Therefore, when teaching conservation of mass during dissolving, it would be best to teach properties of dissolution with explanations on concept of particles and size of molecules. Also the “measurement” skill, which is one of the fundamental inquiry skills to be learned, should be carefully taught in order to prevent students from forming misconceptions on the law of conservation of mass.

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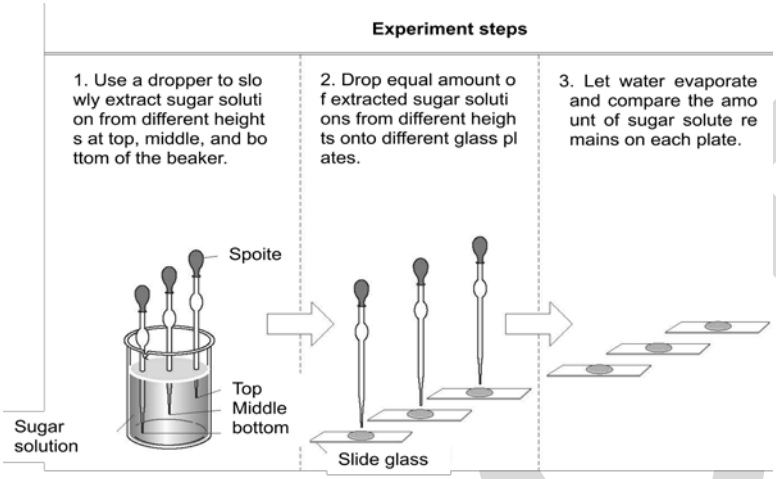
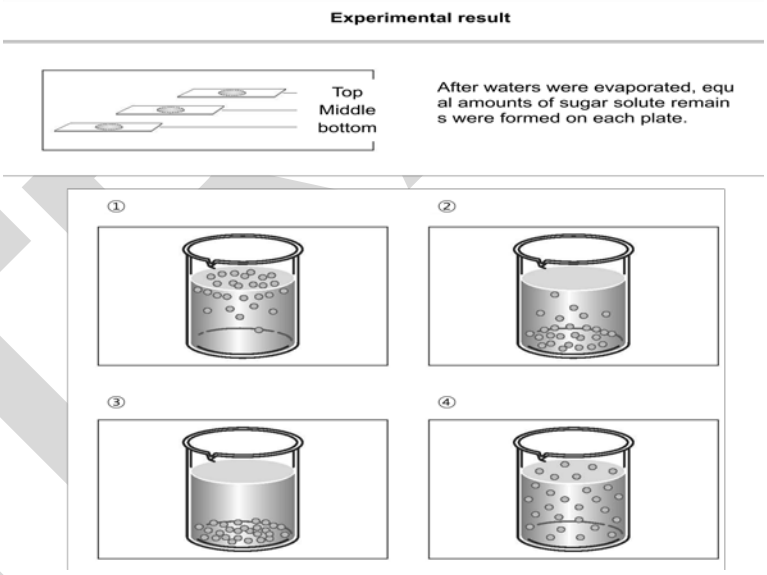
3.3.3 Question 3. Solution properties

Question 3. Jane left the sugar-dissolved solution out in the open from question 2 for a day, and imagined how the sugar solute would look as illustrated in the figure below.

Jane performed the following experiment to confirm her imagination.



Please select a figure that correctly depicts the sugar solute remains from the experiment. Mark the correct answer choice number in your answer sheet, and also explain why you chose the particular answer choice.



Explanation:

Table 8. Percentage of correct answers on question 3 by class year

Year	Responded type	Question 3 0	1	2	3	4	5	6	7	9	Total
5th	Probability	7	41	63	13	51	38	62	144	2	421
	%	1.7	9.7	15.0	3.1	12.1	9.0	14.7	34.2	.5	100.0
6th	Probability	11	98	111	106	107	29	73	236	6	777
	%	1.4	12.6	14.3	13.6	13.8	3.7	9.4	30.4	.8	100.0
Total	Probability	18	139	174	119	158	67	135	380	8	1198
	%	1.5	11.6	14.5	9.9	13.2	5.6	11.3	31.7	.7	100.0

Table 9. Percentage of correct answers on question 3 by gender

Year	Sex	Responded type	Question 3 0	1	2	3	4	5	6	7	9	Total
5th	Girl	Probability	2	18	37	4	19	19	36	71	1	207
		%	1.0	8.7	17.9	1.9	9.2	9.2	17.4	34.3	.5	100.0
	Boy	Probability	5	23	26	9	32	19	26	73	1	214
		%	2.3	10.7	12.1	4.2	15.0	8.9	12.1	34.1	.5	100.0
6th	Girl	Probability	1	50	55	55	41	10	33	104	3	352
		%	.3	14.2	15.6	15.6	11.6	2.8	9.4	29.5	.9	100.0
	Boy	Probability	10	48	56	51	66	19	40	132	3	425
		%	2.4	11.3	13.2	12.0	15.5	4.5	9.4	31.1	.7	100.0

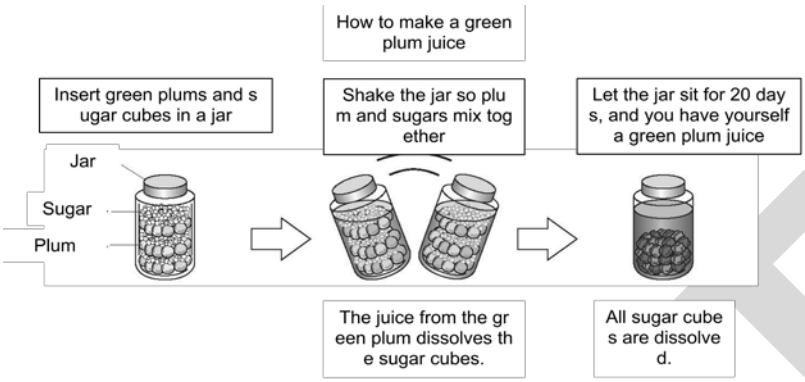
The fundamental inquiry skills imposed by this question are “data analysis” and “inference”. The question asks if the concentration level of the sugar cube-dissolved solution is the same at the top, middle, and bottom of the solution. The percent correct on this particular question was 11.6%, which is lower than the overall percent correct.

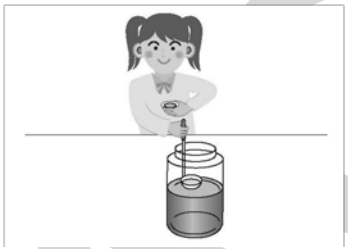
Sixth graders whose academic curriculum covered the question material scored 12.6%, which was slightly better than 9.7% of fifth graders whose academic curriculum did not cover the question material, but both of their scores, were still quite low. The low scores were likely caused by the fact that students had to not only chosen the correct answer choice, but also had to provide the reasoning behind their answer choice, a task that many of them failed to complete. It shows that many students were challenged to display the inquiry skill of inferring a conclusion from the given data that the sugar cube was evenly dissolved within the water.

30.4% of sixth graders who had already learned of this particular material chose wrong answer choice ③, a choice that illustrated for more sugar sitting at the lower part of the beaker. This probably comes from student’s daily experience of dissolving sugar in water beyond the saturation point, in which case oversaturated sugars sit at the bottom of the solvent. It shows that student’s daily experience forms preconception, and preconceptions win over learning experience in inquiry learning process.

3.3.4 Question 4. Solution properties

Question 4. Jane made a green plum juice using sugar cubes.





Jane tasted the top part of the plum juice.

Please select from one of the followings that correctly explains the amount of concentration of the dissolved sugar in plum juice. Mark the number of correct answer choice in your answer sheet.

① The sugar is thinner at the top than the bottom part of the jar.

② The sugar is stronger at the top than the bottom part of the jar.

③ The concentration of sugar is equal at the top and bottom of the jar.

④ The sugar did not dissolve at the top.

Table 10. Percentage of correct answers on question 4 by class year

Year	Response type	Question 4						Total
		0	1	2	3	4	9	
5th	Probability	1	163	66	173	18	0	421
	%	.2	38.7	15.7	41.1	4.3	.0	100.0
6th	Probability	2	244	85	413	29	4	777
	%	.3	31.4	10.9	53.2	3.7	.5	100.0
Total	Probability	3	407	151	586	47	4	1198
	%	.3	34.0	12.6	48.9	3.9	.3	100.0

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Table 11. Percentage of correct answers on question 4 by gender

Year	Sex	Response type	Question 4 0	1	2	3	4	9	Total
5th	Girl	Probability	0	83	33	80	11	0	207
		%	.0	40.1	15.9	38.6	5.3	.0	100.0
	Boy	Probability	1	80	33	93	7	0	214
		%	.5	37.4	15.4	43.5	3.3	.0	100.0
6th	Girl	Probability	0	122	35	180	12	3	352
		%	.0	34.7	9.9	51.1	3.4	.9	100.0
	Boy	Probability	2	122	50	233	17	1	425
		%	.5	28.7	11.8	54.8	4.0	.2	100.0

The comprehensive inquiry function tested in this question was "generalization", and this real life application of question 3 asks whether the solution's concentration vary or not by its position in terms of top, middle, and bottom of the jar. The percent correct on this question was 48.9%, which is similar to the overall percent correct.

The percent correct was higher in sixth grade than in fifth grade, and it was higher in boys than in girls. It shows, based on day-to-day experiences the inquiry skills are higher in older class year than in younger class year and higher in boys than in girls.

34% of test-takers chose wrong answer choice ①, and it shows that a good portion of students expect sugar to sink to the bottom of solution as in question 3.

Questions 3 and 4 scoop for student's preconception on dissolution and solutions, and it was shown that many students are exposed to a preconception that particles sink to the bottom of solution after dissolving and therefore, the solution's concentration is highest at the bottom. It also showed that a preconception formed from an everyday experience is not easily altered.

4. CONCLUSION

This study develops inquiry-based assessment questions by modifying and reinforcing the NAAA by NIER of Japan to match 2007 amendment of science education curriculum of Korea. The assessment was given to fifth and sixth grade students, and the responses were collected for analysis. The percentages of correct answers and commonly chosen wrong answers from the assessment were ascertained, and students' inquiry abilities were able to be determined.

The following conclusions were made from this study. First, scientific inquiry abilities of fifth and sixth graders in Korea elementary school are lower than that of their general school's assessment. If the most ideal form of learning scientific knowledge is in making scientific inquiries, inquiry-based assessment would be the most appropriate assessment method for fulfilling the ultimate goal of science education as the inquiry-based assessment encourages students to naturally learn not only the scientific information and concept but also the inquiry skills.

Second, students' preconceptions and misconceptions could be obtained from commonly chosen wrong answers in the inquiry-based science assessment. Students' preconceptions and misconceptions have effects on their inquiry abilities, and therefore, academic institutes should help students correct their preconceptions and misconceptions that may interfere with the development of inquiry skills.

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