Trends of Science Ability in the National Assessment of Educational Achievement (NAEA) of Korean Ninth Graders

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The results of the National Assessment of Educational Achievement from 2010 to 2013 have shown a downward trend in ninth graders' science average achievement scores from 2011 to 2013. The percentage of students in the Advanced level decreased dramatically from 19.95% in 2010 to 11.48% in 2013, while the percentage of students in the Basic level showed an increase. By analyzing several statistics such as the percentage of correct answers, item discrimination, and average response rate by achievement level, we were able to identify possible discrepancies between students' academic abilities and their respective curriculums. In addition, the characteristics of each level of student achievement were defined so that we could help students, teachers, and schools by providing them with basic information. We also included discussions on how to fine tune the achievement standards of the science curriculum as well as how to implement improved and customized teaching and learning methods.

Keywords: National Assessment of Educational Achievement (NAEA), science achievement, Trends of 2010–2013 NAEA, trends of ratio of achievement level, achievement characteristics

INTRODUCTION

For many countries around the world, understanding educational outcomes is very important in order to effectively plan educational systems and reform. Both technologically advanced and innovative countries have participated in international comparative studies of educational achievement in several curriculum

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areas such as reading, mathematics, and science. The results of these international comparative studies have provided administrators, educational policymakers, teachers, parents, and researchers with insights on how to improve the educational environment as well as how to accomplish better educational systems. Participating countries also put in the effort to monitor their own educational system as well as hold schools accountable by conducting national level achievement tests in order to remain competitive in the future. As a technologically advanced country, Korea's results in the international and national achievement assessments suggest that Korea's education system is competent for Korean elementary, middle, and high school students. Starting with the participation in the Trends in International Mathematics and Science Study (TIMSS) overseen by the International Association for the Evaluation of Educational Achievement (IEA) in 1995 and continuing with the Program for International Student Assessment (PISA) administered by the Organization for Economic Cooperation and Development (OECD) in 2000, South Korea has gained international attention for performing highly in subjects such as reading, mathematics, and science (ACER, 2011; Martin, Mullis & Foy, 2012; Mullis, Martin & Foy, 2012; OECD, 2004; OECD, 2007; OECD, 2014a; OECD, 2014b).

Based on the outcome of these international assessments, there is a gradually improving trend in the achievement of Korean students in science. The achievement in science among eighth graders was exceptional: they placed fourth in 1995, fifth in 1999, third in 2003, fourth in 2007, and third in 2011 in the TIMSS. Furthermore, Korea was one of the top performing countries in the PISA, ranking first out of 41 countries in 2000, fourth out of 40 countries in 2003, seventh to 13th out of 47 countries in 2006, fourth to seventh out of 75 countries in 2009, and fifth to eighth out of 65 countries in 2012. These accomplishments indicate a high level of achievement among Korean students in science compared to other countries.

Multiple factors could have contributed to Korea's exceptional achievements in education, including maintaining the quality of the academic curriculum on a national level and setting the nation's educational policy by conducting the National Assessment of Education Achievement (NAEA) every year since 1998.

While the goal of the assessment has varied depending on changes in government policy, the underlying purposes of the NAEA are as follows: 1) evaluate student achievement levels and assess how close students are to meeting the curriculum's objectives, which in turn will help to identify any shortcomings the current curriculum may have as well as potential solutions; 2) allow scientific and systematic assessment of the level of academic achievement of elementary, middle, and high school students as well as understand the trends of their achievement levels in order to set the course of education, which will increase international competitiveness and provide a foundation for creating concrete and viable educational policies; and 3) develop innovative and suitable evaluation methods

State of the literature

- Korea has been maintaining the quality of its academic curriculum on a national level, and also in order to set the nation's education policy it has been conducting the National Assessment of Education Achievement (NAEA).
- The results of the NAEA will help to evaluate the effectiveness of the current curriculum and identify any shortcomings it may have. Furthermore, it contributes to the improvement of evaluation methods in schools.
- The use of the NAEA has been known to have a great impact on the accountability of school performance and on educational practices such as teaching and learning methods.

Contribution of this paper to the literature

- The analysis of the NAEA science achievement results helps to improve the curriculum, teaching and learning methods, and student evaluation.
- The achievement characteristics of Korean ninth-grade students by achievement level in science subjects were defined.
- The results of the NAEA suggest that the current Korean middle-school science curriculum needs fine tuning in terms of difficulty level and contents.

that allow teachers and schools to improve their own evaluation methods (Jeong et al., 2004; Kim et al., 2012d; Lee et al., 2010).

Many countries administer assessments on a national level in order to monitor their curriculum and survey student achievement. The National Assessment of Educational Progress is a national assessment administered in the USA in order to monitor students' academic achievement and progress, while similar assessments are administered in UK (the National Curriculum Assessment) and Germany (VERA, Vergleichsarbeiten in der Schule).

The NAEA in South Korea is conducted based on the national laws (ESEA, 2013; EDESEA, 2013; LAA, 2014; LEAA, 2013), which make this assessment a national obligation for all schools. The purpose of the NAEA is to manage the quality of education and monitor the adequacy of the academic curriculum. On these legal grounds, the Korea Ministry of Education commissions the Korea Institute for Curriculum and Evaluation (KICE) to plan and conduct the educational assessment. On a national level, Korea has made efforts to collect data on the proportion of students who are classified in the *Below Basic* achievement level of the education assessment. The Ministry of Education has been providing administrative and financial support and implementing various programs in Innovative Management Schools—schools with high rates of Below Basic level students—in order to enhance their quality of education (MEST, 2008; MEST, 2009a; MEST, 2009b).

The current study is data-driven research based on the Korean NAEA science achievement results from 2010 to 2013 designed to help policy making. Taking into account the purpose of the NAEA, which is to monitor the curriculum and control the quality of education, various data were analyzed, such as changes in average scores and standard deviations, trends in the levels of achievement, and trends of the ratio of achievement for each level for the NAEA science achievement results from 2010 to 2013. By analyzing the results and trends of science achievement, the existing data can be used to improve the future curriculums by determining the mismatch between what ninth-grade students are expected to know and what the previous curriculum contained.

METHODOLOGY

This study analyzed the results of the Science Achievement Assessment from 2010 to 2013. Based on the data from these four years, we analyzed the changes in the average scores and their standard deviations, trends in levels of achievement, and trends in the ratio of achievement for each level for the Science Achievement Assessment. While all ninth graders were evaluated from 2010 to 2012, in 2013 a sampling evaluation of 1.29% of ninth graders (approximately 7,600 students) was performed. Because these participants were chosen using the stratified cluster sampling method, which yielded an almost negligible sampling error, they were an appropriate representation of the ninth-grade population.

Overview of the National Assessment of Educational Achievement (NAEA) in Science from 2010 to 2013

Korea's national curriculum for elementary schools and its modern teachers colleges were established in 1895 immediately after the *Gabo* Reforms in 1894 that stimulated Korea's modernization (Kim et al., 2012b). The Korean academic curriculum has been regulated at the national level ever since the restoration of Korea's independence from Japan in 1945. The First National Curriculum was established in 1954, after the end of the Korean War. Since then, the curriculum has been constantly updated. The Seventh Curriculum was implemented from 1997 to 2007. It was replaced by the 2007 Revised Curriculum, which has been frequently adjusted since its inception (NCIC, 2010).

Table 1. Overview of NAEA in science subjects from 2010 to 2013

Year	Participants	Evaluation Scope	Curriculum	Number of Items	Test Length	Test Date
2010	9th grade (all population)	7th Science 8th Science 9th Science (First half of curriculum)	The 7th National Science Curriculum			July 14
2011	9th grade (all population)	7th Science 8th Science 9th Science (through Unit 3)	The 7th National Science Curriculum	40 item items including 32 multiple choice and 8 constructed-response items	60 mins	July 12
2012	9th grade (all population)	7th Science 8th Science 9th Science (through Unit 2)	2007 Revised Science Curriculum			June 26
2013	9th grade (sampling)	7th Science 8th Science 9th Science (through Unit 2)	2007 Revised Science Curriculum			June 25

Table 1 is a general overview of the Science Achievement Assessment conducted from 2010 through 2013.

As the Seventh Curriculum was implemented, the scope of the Science Achievement Assessment for 2010 and 2011 included material from seventh-, eighth-, and the first half of the ninth-grade curriculum (Kim, Lee, Jeong & Sin, 2011; Kim, et al., 2012a). In 2012 and 2013 the curriculum changed to the 2007 Revised Curriculum. Due to the fact that only some schools implemented the Intensive Learning Curriculum, there was a difference in the school materials covered in each school.

The Intensive Learning Curriculum takes different school characteristics into account, in that a school can open an intensive course for certain subjects and grades during a semester depending on a school's circumstances. Before the Intensive Learning Curriculum was implemented, curriculum composition was uniformly applied throughout schools without taking into account a school's situation or the characteristics of each subject. Thus, because all schools would progress through the curriculum on a similar pace, there were no intensive courses, and the range of examinations was based on the order of the curriculum. Therefore, a survey was conducted to find out what common content areas in science students learned, and the scope of what was tested was determined accordingly (Kim et al., 2012a; Lee, Sim, Kim, Lee & Lee, 2014b).

The reason for replacing the Seventh Curriculum with the 2007 Revised Curriculum was to introduce subject and grade clusters. The 2007 Revised Curriculum also guarantees the autonomy of the school curriculum and introduces the Intensive Learning Curriculum. However, curriculum changes in the sciences are minimized in the content side, as seen in Table 2. Table 2 presents the middle school science content of the Seventh Curriculum and 2007 Revised Curriculum.

The assessment framework developed in 2010 that was utilized for this assessment consists of two dimensions: the Content Domain and the Cognitive Domain (Figure 1). (Jeong et al., 2010).Following the national curriculum, the Content Domain is divided into four sections: Motion and Energy, Matter, Life, and Earth and Space. The Cognitive Domain has two sections, Knowledge and Inquiry, each containing subsections. The purpose of the Knowledge section is to assess the ability to understand basic science concepts through investigating nature as well as the ability to apply them to real life. Scientific knowledge is described as the

Table 2. A comparison of the science content of the Seventh Curriculum and 2007 Revised Curriculum

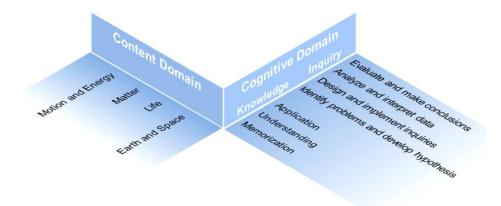| Grade	Seventh Curriculum			2007 Revised Curriculum		
	7th	**8th**	**9th**	**7th**	**8th**	**9th**
Motion and Energy	・Light ・Force ・Waves	・Different type of motions ・Electricity	・Work and energy ・Action of current	・Force and motion ・Electrostatics	・Thermal energy ・Light and waves	・Work and energy ・Electricity
Matter	・Three phases of matter ・Molecular motion ・Phase change and energy	・Nature of matter ・Separation of mixtures	・Composition of substances ・Regularity in change of matter	・Three phases of matter ・Molecular motion ・Phase change and energy	・Composition of substances ・Compounds around us	・Nature of matter ・Electrolytes and ions
Life	・Organization of living organisms ・Digestion and circulation ・Respiration and excretion	・Structure of plants and their functions ・Stimulus and response	・Reproduction and development ・Genetics and change	・Organization and diversity of living organisms ・Plant nutrition	・Digestion and circulation ・Respiration and excretion	・Stimulus and response ・Reproduction and development
Earth and Space	・Structure of earth ・Crust materials ・Composition and movement of sea water	・Earth and stars ・History of earth and crustal movements	・Circulation of water and weather change ・Solar system and movement	・Earth and space, crust materials and changes ・Tectonic movements and plate tectonics	・Solar system ・Stars and the universe	・Characteristics of the atmosphere and weather change ・Composition and movement of sea water

Figure 1. The assessment framework of NAEA Science Achievement Assessment developed in 2010

intellectual products—such as facts, concepts, theories, and laws—that were obtained through the process of scientific research. In the Knowledge section we assess three distinct abilities: memorization, understanding, and application. The ability to memorize is determined by whether or not a student knows scientific terms or facts; the ability to comprehend is determined by whether or not students are able to understand and define different scientific facts, concepts, theories, and laws; and the ability to apply is determined by whether or not a student is able to recognize a scientific fact, concept, theory, or law in a real world context (Kim et al., 2011). The Inquiry section is designed to enhance students' ability to investigate

nature in a scientific manner and apply it to real life. Typically inquiry ability includes the capability to observe, classify, measure, predict, and reason; however, the science achievement assessment seeks to assess aforementioned inquiry abilities as well as integrated inquiry abilities. The integrated inquiry ability is the ability to identify problems and develop hypotheses in given situations, to design and implement inquiries to solve problems, to analyze and interpret data to reach meaningful results, and to evaluate and make conclusions using relevant resources (Kim, Lee, Kim, Jeong & Kang, 2012a). The characteristics of the achievements levels are based on the content domain and cognitive domain of the assessment framework.

Data analysis

The data were analyzed to identify the trends in the results of the achievement assessments from 2010 to 2013 based on average score and standard deviation. Changes in the trend in the proportion of students in each achievement level were also examined over the years. The average percentage of correct answers and standard deviation were analyzed by different science content areas as well. In addition, several values, such as the percentage of correct answers, item discrimination, and average response rate by achievement level, were analyzed for 128 items in the science achievement assessment from 2010 to 2013.

The modified Angoff procedure was used to set the standard of the NAEA (Angoff, 1971). This is a standard-setting procedure for setting up a criterion-referenced passing point. The passing point was set by a group of experts who specialize in a subject area. The first step of the procedure is to define a hypothetical "minimal competence." Then, experts from each subject area define the respective characteristics of each achievement level on the basis of the curriculum. The experts predicted the percentage of correct answers for each item and these values were averaged. This process was repeated a number of times to determine the cutoff point, and the academic characteristics of each achievement level were defined accordingly. For each standard level, the representative items were selected and analyzed. A representative item exhibits the degree of comprehension of each student by achievement level. The achievement assessment result classifies the students into four different achievement levels—Advanced, Proficient, Basic, and Below Basic levels. Each achievement level is determined according to the degree of comprehension of the basic content of the curriculum, and scores that divide the proficiency levels are set based on the modified Angoff method, which is applied to the result of the assessments each year (Angoff, 1971).

To discuss the results of the achievement assessment and define the academic characteristics of each achievement level, 12 science education experts, science teachers, and professionals from the Ministry of Education met to draw implications from the science content and curriculum as well as teaching and learning methods. These experts also discussed the implications of the results as well as related educational issues in order to use these finding to support effective educational policy.

RESULTS

Trends in the science achievement assessment results

Table 3 shows the average and standard deviation of the ninth-grade science achievement assessment results from 2010 to 2013. The average scale score average for 2013 is 193.99 and the standard deviation is 29.10, which shows a decline compared to 2010 and 2011.

Figure 2 illustrates the proportion of students in each achievement level and the trend of those proportions over the years. Overall the proportion of *Proficient*-level

Table 3. The mean and standard deviation of ninth-grade science achievement assessment results* (Lee et al., 2014a, p155)

Year	Number of Test Participant Students	Mean of Achievement Score		Standard Deviation
2010	658,303	196.25		33.61
2011	634,974	198.84	(▴2.59)	30.35
2012	624,513	195.56	(▽3.28)	29.08
2013	7,654	194.99	(▽0.57)	29.10

▴: *increase from last year,* ▽: *decrease from last year*

Note. The current scoring system of the NAEA was established in 2010. It was devised to classify students into achievement levels by using scale scores, average score, and standard deviation (Kim et al., 2012c).
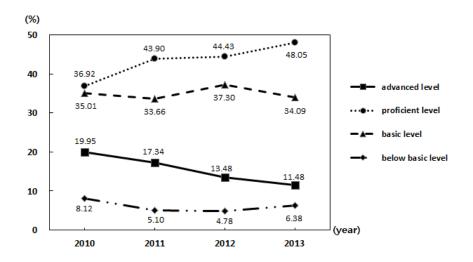

Figure 2. Proportion of students in each achievement level (Lee et al., 2014a, p. 156)

students was the highest, followed by the Basic-level students; students who fall below the basic level had the lowest proportion.

The percentage of students in the *Advanced* level decreased dramatically from 19.95% in 2010 to 11.48% in 2013, and decreased from 2010 to 2013. In particular, the proportion of Advanced level students in 2012 decreased by 6.47% compared to 2010. On the other hand, the proportion of students in the Proficient level increased every year, and in 2012 increased by 7.51% compared to 2010; the percentage of students in the Proficient level in was 36.92% in 2010 and 48.05% in 2013. The proportion of students in the Basic level has been averaging about 35% from 2010 to 2013. While the proportion of students in the Below Basic level decreasing to 4.78% in 2012, in 2013 the proportion increased to 6.38%. According to these results, the decrease in the proportion of students in the Basic and Below Basic levels might be the result of policy initiatives to improve the academic abilities of low-achieving students that started in 2012, when the total evaluation was implemented (Kim et al., 2013).

The increase in the scientifically literate population was positive news; however, as the evaluation method changed to sampling in 2013, the positive trend discontinued. The fact that the proportion of Advanced-level students decreased over the years will negatively affect the fostering of students who want to enter the field of science. Considering that society in the 21st century is knowledge based and that the heart of national competitiveness depends on a nation's quality of science

and technology, the decrease in the proportion of Advanced-level students and the decline in the overall science achievement level is a concern and needs immediate attention.

Characteristics of the distribution of percentage of correct answers and item discrimination by subject
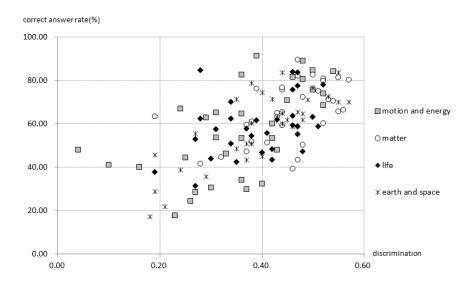
Table 4 illustrates the average percentage of correct answers and standard deviation by science topic and proficiency level. According to the results, the Matter section had the highest percentage of correct answers followed by the Life, Earth and Space, and Motion and Energy. The section that had the biggest deviation between the Advanced students and the Below Basic students was the Motion and Energy section followed by the Earth and Space, Matter, and Life. Also, the standard deviation of each of the different achievement levels increased as the achievement level decreased.
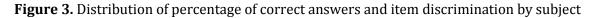
The results show that, compared to the Advanced- and Below Basic-level students, the standard deviation of the Proficient- and Basic-level students was almost two times greater. This means that the scores of the Proficient- and Basic-level students were more dispersed than those of the Advanced- and Below Basic-level students.

Percentage of correct answers and item discrimination for each science topic are shown in Figure 3. Among the 128 items, those in the Motion and Energy section show an even distribution, while there were also two items that had a correction

Table 4. Average and standard deviation of percent correct by specific topic and achievement level in ninth-grade science

Science Subject	Advanced Level	Proficient Level	Basic Level	Below Basic Level	Average of Levels
Motion and Energy	82.97 (16.59)	63.85 (25.21)	43.42 (22.32)	21.47 (7.82)	57.03 (21.04)
Matter	93.32 (6.65)	76.58 (16.42)	47.10 (16.93)	18.85 (6.08)	65.34 (13.74)
Life	88.86 (6.54)	68.05 (11.98)	41.58 (12.75)	19.26 (5.37)	58.95 (10.06)
Earth and Space	86.16 (15.41)	67.38 (21.50)	41.41 (15.82)	18.62 (5.74)	58.23 (17.07)

Figure 3. Distribution of percentage of correct answers and item discrimination by subject

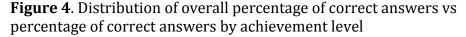rate of 40% and low item discrimination. Meanwhile, in the Earth and Space section there were two or three items that had a correction rate of 30% or lower and low item discrimination. However, generally the items in all sections had favorable item discrimination and also correct answer ratio.

Figure 4 is a graph that illustrates the percentage of correct answers and item discrimination of different achievement levels. The percentage of correct answers and item discrimination of Below Basic students was lower for more difficult items. On the other hand, for easier items the item discrimination was high for not only Advanced and Proficient students, but also for others in different achievement levels. However, the percentages of correct answers of Below Basic-level students decreased even for easier items.

Figure 4. Distribution of overall percentage of correct answers vs percentage of correct answers by achievement level

Representative items by subsection and characteristics of students by achievement level

Table 5 shows the number of items representing each achievement level for the subsections of the Motion and Energy section from 2010 to 2013. From 2010 to 2013 in the Motion and Energy section there was one item each in 2010 and 2013 (two items total) that represented the Basic level, 10 items that represented the Proficient level, 12 items that represented the Advanced level, and 8 items that represented the above Advanced level. These give information on the achievement levels of Advanced and Proficient students that will in turn provide us with meaningful implications regarding teaching and learning methods specific to these students. However, there are not much data on students in the Basic and Below Basic levels. This limits us from providing suggestions on how to work with such students. The Motion and Energy section can be divided into four subsections: Force and Motion, Heat, Electricity and Magnetism, and Light and Waves. Of the 15 items in the Force and Motion subsection, four items were Advanced level, 5 were Proficient level, and one was Basic level. Five items were written for the Electricity and Magnetism subsection, all of which were Advanced-level items. This agrees with Kim and Lee (2006), whose study showed that students struggle the most with Electricity and Magnetism. The Light and Waves subsection has a total of 10 items: three items for Advanced, four items for Proficient, and one item for Basic.

In the Matter section from 2010 to 2013, there were one Basic-level item, 19 Proficient-level items, and 12 Advanced-level items (Table 6). Information from these items provide information on the achievement level of both Advanced and Proficient students, which can be used to practice better teaching and learning methods.

Table 5. Number of items representing each achievement level for the subsections of the Motion and Energy section

Subsection	Year	Number of Items	Number of Items Representing Each Achievement Level			
			Advanced	Proficient	Basic	Below Basic
Force and Motion	2010	4	1	-	-	-
	2011	4	0	2	-	-
	2012	4	2	1	-	-
	2013	3	1	2	-	-
Heat	2012	1	-	1	-	-
	2013	1	-	-	-	-
Electricity and Magnetism	2010	1	1	-	-	-
	2011	3	3	-	-	-
	2013	1	1	-	-	-
Light and Waves	2010	3	1	2	-	-
	2011	1	-	1	-	-
	2012	3	1	1	-	-
	2013	3	1	-	1	-

The Heat section was introduced in the 2007 Revised Curriculum

Table 6. Numbers of items representing each achievement level for the subsections of the Matter section from 2010 to 2013

Subsection	Year	Number of Items	Number of Items Representing Each Achievement Level			
			Advanced	Proficient	Basic	Below Basic
State and Change of Matter	2010	2	-	2	-	-
	2011	3	-	3	-	-
	2012	3	2	1	-	-
	2013	3	1	2	-	-
Structure of Matter	2010	3	1	2	-	-
	2011	2	-	1	1	-
	2012	2	2	-	-	-
	2013	2	1	1	-	-
Characteristics of Matter and Separation of Mixtures	2010	3	2	1	-	-
	2011	3	1	2	-	-
	2012	3	1	2	-	-
	2013	3	1	2	-	-

The Matter section consists of three different subsections: State and Change of Matter, Structure of Matter, and Characteristics of Matter and Separation of Mixtures. Of the 11 items in the subsection State and Change of Matter, three were considered to be in the Advanced level and eight were in the Proficient level. In the Structure of Matter subsection, four of the nine items were in the Advanced level, four were in the Proficient level, and one was in the Basic level. Among the 12 Characteristics of Matter and Separation of Mixtures subsection items, five were in the Advanced level and the rest were considered to be Proficient level items. Because the proportion of Advanced level items on topics like Structure and Characteristics of Matter were very high, we know that students were struggling with this topic. This is likely because the exploration of the structure of matter on a microscopic scale is beyond the cognitive level of middle school students.[1]

Table 7 shows the number of items representing each achievement level for the Life subsections from 2010 to 2013 for ninth-grade students. The Life section during the years 2010 to 2013 contained one Basic-level item, nine Proficient-level items, 19 Advanced-level items, and three Above Advanced-level items. These results provide more than enough evidence to determine the achievement level of Advanced students, while evidence for Proficient students is partial at best. Moreover, evidence in determining the achievement levels of Basic students is very limited.

The Life section can also be divided into three subsections, the Organization of Life and Diversity, Plants, and Animals. Of the five total items for the Organization of Life and Diversity subsection, four were Advanced-level items and one was a Proficient-level item. There were a total of nine items in the Plant subsection; seven were Advanced-level items and there was one each in the Proficient level and the Above Advanced level. This is in line with research stating that the Plant subsection

Table 7. Number of items representing each achievement level for the subsections of the Life section from 2010 to 2013

Subsection	Year	Number of Items	Number of Items Representing Each Achievement Level			
			Advanced	Proficient	Basic	Below Basic
Organization of Life and Diversity	2010	1	-	1	-	-
	2011	1	1	-	-	-
	2012	2	2	-	-	-
	2013	1	1	-	-	-
Plant	2010	2	2	-	-	-
	2011	2	1	-	-	-
	2012	1	1	-	-	-
	2013	4	3	1	-	-
Animal	2010	5	2	2	1	-
	2011	5	2	3	-	-
	2012	5	3	2	-	-
	2013	3	1	-	-	-

[1] Because each item goes through a process of equating, it cannot be the case that the item itself was too difficult for the students.

Table 8. Number of items representing each achievement level for the subsections of the Earth and Space section from 2010 to 2013

Subsection	Year	Number of Items	Number of Items Representing Each Achievement Level			
			Advanced	Proficient	Basic	Below Basic
Geology	2010	3	1	2	-	-
	2011	3	2	1	-	-
	2012	4	-	1	-	-
	2013	4	-	3	-	-
Astronomy	2010	2	1	1	-	-
	2011	4	1	3	-	-
	2012	4	2	1	-	-
	2013	4	-	3	-	-
Atmosphere and Ocean	2010	3	2	1	-	-
	2011	1	-	1	-	-

of the Life section was the most difficult for students (Kim et al., 2013). Among the 18 Animal section items, eight were Advanced-level, seven were Proficient-level, one was a Basic-level, and two were Above Advanced-level items.

Table 8 illustrates the results by subsection of the Earth and Space section in the Science Achievement Assessment for 2010-2013 for ninth-grade students.Of the 32 items in the Earth and Space section, not a single Basic-level item was published from 2010 to 2013. There were 10 Advanced-level items, 16 Proficient-level items, and six Above Advanced-level items. Looking at these results, we were able to collect more than enough evidence to determine the achievement level of Proficient-level students and to a lesser extent the achievement level of Advanced students. However, we did not have sufficient evidence regarding Basic-level students. In particular, the fact that of the 32 Basic-level items in the assessment there was not a single item on Earth and Space needs more in-depth analysis. There are several possibilities for this: the level of the current middle-school curriculum for the Earth and Space section, exclusion of the Space unit from the eighth-grade final exams, lack of teachers who majored in Earth and Space, and/or the decline in the academic ability of middle school students.

The Earth and Space section from 2010 to 2013 included 14 items each in the Astronomy and Geology subsections and four items in the Atmosphere and Ocean subsection. Of the 14 items in the Geology subsection, four were Above Advanced-level items, four were Advanced-level items, and the remaining six were Proficient-level items. In the Astronomy subsection the Above Advanced-, Advanced-, and Proficient-level items had two, four, and eight items, respectively. The Atmosphere and Ocean subsection had two items each for the Advanced and Proficient levels. There are only a few items on the Atmosphere and Ocean subsection because this section was taught mostly in the ninth grade, and was therefore not covered by the time of the assessment, which is conducted on June of the ninth grade. When we compare the Geology and Astronomy subsections, Geology had a relatively low percentage of correct answers and contained more Advanced-level items. These results imply that the current geology curriculum, which contains topics on tectonics, could possibly be too difficult for the current level of students and therefore its inclusion needs to be reexamined.

The characteristics of each achievement level were based on the analysis of the cognitive characteristics of representative items. Representative items were selected using a standard that exemplifies the characteristic of each achievement level and the cognitive characteristics of each representative item is based on the text, data, and answers. Through this process the statements on each achievement level have been developed and modified by current teachers and experts such that each proficiency level can be best represented. However, because the statements on each achievement levels are written based on the items, there are concerns over the fact that the characteristics of achievement levels change depending on the items evaluated each year. Therefore, in this study the characteristics of the achievement levels are defined as shown in Table 9.

These definitions are based on the results of the achievement assessments and item analyses from 2010 to 2013 and are a product of the work of a special committee of experts. As described in the Methodology section, the representative items were selected based on the percentage of correct answers in four years of data. For each representative item the achievement standards were then divided

Table 9. Definition of academic characteristics of students by achievement level (ability of achievement levels) in science

Advanced	• Ability to understand abstract concepts of motion and energy, matter, life, and earth and space and apply them to real-life phenomena.
	• Possession of basic inquiry skills such as observation, classification, and measurement as well as integrated inquiry skills such as problem identification and hypothesis development, design and implementation of experiments, data analysis and interpretation, drawing conclusions, and assessment.
	• Ability to apply knowledge about force and motion, electricity, heat, and light and waves to new situations and ability to understand and explain data in tables and graphs.
	• Ability to explain states and changes of matter, structures and properties of matter, and separation of mixtures and also ability to relate these to chemical properties and changes.
	• Ability to collectively explain the functions of life using facts and terms about animals, plants, organization of life, and diversity.
	• Ability to understand abstract concepts in geology, astronomy, and atmosphere and ocean and explain relevant natural phenomena.
Proficient	• Ability to understand basic concepts of motion and energy, matter, life, and earth and space and relate them to real life.
	• Possession of basic inquiry skills such as observation, classification, and measurement and some inquiry skills such as problem identification and hypothesis development, design and implementation of experiments, data analysis and interpretation, drawing conclusions, and assessment.
	• Ability to partially understand knowledge about force and motion, electricity, heat, and light and waves and ability to understand simple tables and graphs.
	• Ability to relate concepts such as states and changes of matter, structures and properties of matter, and separation of mixtures to real-life phenomena.
	• Ability to partially explain the function of life using facts and terms about animals, plants, organization of life, and diversity.
	• Ability to understand some facts about geology, astronomy, and atmosphere and ocean, and relate them to relevant natural phenomena.
Basic	• Knowledge of basic concepts and terms of motion and energy, matter, life, and earth and space.
	• Possession of some basic inquiry skills such as observation, classification, and measurement.
	• Knowledge of basic knowledge about force and motion, electricity, heat, and light and waves.
	• Knowledge of some relevant concepts about states and changes of matter, structures and properties of matter, and separation of mixtures.
	• Knowledge of about facts and terms about animals, plants, organization of life, and diversity.
	• Knowledge of basic terms about geology, astronomy, and atmosphere and ocean.
Below Basic	• More effort required to to understand science concepts and to learn inquiry skills.
	• More effort required to to learn basic concepts and inquiry skills related to familiar scientific phenomena.

into 10 specific steps to describe the achievement level in order to analyze the characteristics of items that represent the Advanced level. Based on this procedure, the characteristics of what students excel in were described for each achievement level. The aforementioned group of experts held several meetings in order to validate and modify the described characteristics of an achievement level. Such definitions are meant to measure a student's academic achievement ability and to provide information on the type of academic skills certain students lack compared to their higher achieving counterparts. These characteristics that we have defined can also be used as a basis for future curriculum revisions.

The use of standard setting for student assessment has been known to have a great impact on the accountability of school performance and on educational practices such as teaching and learning methods and grade-reporting systems. (Resnick, 2006; Scriffiny, 2008; Stiggins, 2001). The education achievement characteristics shown in Table 9 not only provide students, parents, and teachers with information on a student's proficiency level, but also the foundation to develop the current curriculum, teaching and learning methods, and education policy. Based on the results of the NAEA, therefore, it is of utmost importance to provide credible and accurate information.

In addition, it is necessary to improve the use of these education achievement characteristics by enhancing awareness of them in schools. It is therefore crucial to provide teachers with training in accurately utilizing and interpreting the evaluation results and educational achievement characteristics.

CONCLUSION

An analysis of the NAEA science results from 2010 to 2013 revealed a change in the trend of average scores that indicated that the student level of achievement in general increased from 2010 to 2011, but then decreased to below the 2010 level in 2012. From 2011 to 2013, the standard deviation shows that the science proficiency level overall has been standardized downward. There are several possible reasons behind this. Considering the results of the 2012-2013 achievement assessments, the overall level of achievement of middle school students was low. When we analyze all the items from 2010 to 2013 in separate categories—Motion and Energy, Matter, Life, and Earth and Space—of the 32 items in the Motion and Energy section there were only two items that were on the Basic level while 20 items were Above Advanced. In the Matter section there were one Basic-level and 12 Above Advanced-items, in the Life section there was one Basic-level and 22 Above Advanced-level items, and in the Earth and Space section there were no Basic-level items and 16 Above Advanced-level items.

The Motion and Energy section consisted of the subsections Force and Motion, Heat, Electricity and Magnetism, and Light and Waves. Of these subsections, students struggled the most with Electricity and Magnetism, a subsection that had only items that were considered Above Advanced. Many studies have pointed to this fact, thus calling to attention to the need to adjust the achievement standards or enhance teaching and learning methods in this field. The Matter section is divided in to three subsections: State and Change of Matter, Structure of Matter, and Characteristics of Matter and Separation of Mixtures. Among the 12 items in the Structure of Matter subsection, four items were Advanced level, and the percentage of correct answers for these items was lower than for their counterparts in other sections. This indicates that students were having diffculty with Structure of Matter. The Life section is divided into Organization of Life and Diversity, Plants, and Animals subsections. In the Organization of Life and Diversity subsection, four out of the five items were in the Advanced level, and in the Plants section eight out of the nine items were categorized as Above Advanced. In particular, students struggled

with these two subsections. The Earth and Space section is divided into the Geology, Astronomy, and Atmosphere and Ocean subsections. Eight out of 14 items in Geology, six out 14 items in Astronomy, and two of four items in Atmosphere and Ocean were Above Advanced-level items, indicating there were general difficulties in these topics.

We can analyze the reasons behind the overall low level of achievement from a number of different perspectives. First, it is simply the case that the academic ability of middle-school students has declined. Considering the fact that the achievement assessment items are based on the national achievement standards, it can be assumed that a significant number of middle school students fall short of the achievement standards. Another reason behind low educational achievement is the difficulty level of the current curriculum. It is a possibility that the current middle school curriculum standard is higher than the students' cognitive level. Our analysis of specific subsections such as Electricity and Magnetism, Structure of Matter, Organization of Life and Diversity, Plants, and Geology, showed that the level of the scientific concepts in these subsections especially was higher than the cognitive levels of the students. A prime example is the content of the Structure of Matter, which explores the microscopic level of matter. In addition, in 2007 the topic of plate tectonics, previously covered in high school, was added to the middle-school curriculum. Even though the material was readjusted to fit the level of middle-school students, the content itself may have been too difficult for the middle-school curriculum.

Finally, the reason for low achievement could be issues regarding teaching and learning methods. It could be that students were not taught the science curriculum in a manner that focuses on investigation and inquiry. In-depth research on the Life section items from 2011 to 2013 showed that middle-school students are inept in practicing logical inquiry, suggesting that classes were focused on lectures and teaching fragmentary knowledge rather than concentrating on practice-based inquiry. Furthermore, in the Structure of Matter subsection there were very few opportunities for students to actually experiment and research, causing students to lose interest compared to other subsections. Therefore, if students can approach learning about the Structure of Matter in a more interesting way—such as using models and structure of familiar matter—we can look forward to higher achievement levels in this section. Meanwhile, the standard deviation of Proficient- and Basic-level students was twice as large as that of the Advanced- and Below Basic-level students. This means that there are large differences among students within the achievement levels. Therefore, there is a need for customized teaching and learning instructions to close this gap.

In conclusion, ninth-grade students' mean and standard deviation of science NAEA achievement showed a downward trend from 2010 to 2013. In addition, the results of the item analysis for these four years showed that students experienced difficulty with the Electricity and Magnetism subsection in the Motion and Energy section, the Structure of Matter subsection in the Matter section, the Plants subsection in the Life section, and the Geology and Astronomy subsections in the Earth and Space section. Given that the science items specify the achievement standards, the academic performance of middle-school students did not meet the achievement standards. It is necessary to figure out the exact difficulty level of curriculum contents for the particularly difficult chapters. Also, it is necessary to provide relevant teaching and learning methods depending on the achievement level.

IMPLICATIONS

We have some suggestions based on these results. First, there needs to be a readjustment in the contents of the achievement levels. The Seventh Curriculum and the 2007 Revised Curriculum include efforts to reduce the burden of studying, for example, by adjusting workload and difficulty levels. However, while portions of the content were either reduced or moved to different grade levels, the difficulty and standards of the material were not changed. The most recent national achievement assessments showed results similar to this study, suggesting that readjustments in the achievement standards of the Science Curriculum should be considered. In other words, if the results of the achievement evaluation continue to decline in specific subsections in the relevant curriculum, then it is necessary to reconsider the achievement standards. An in-depth study using the results of the NAEA is necessary to determine why students are having difficulty with certain topics. Also it is necessary to readjust content such that it corresponds to the cognitive level of middle-school students. Recently there have been discussions on whether to integrate the liberal arts and natural science curriculums in high school and also to reform the middle-school curriculum; a decision will be made in 2015 (NCRRC, 2014). The most important factor in changing the curriculum is content optimization. It is crucial to properly set up what kind of content to learn, when to learn it, and how much to learn.

Second, basic information can be provided in order to better teach ninth graders the parts that were found to be difficult when analyzing the results from 2010 to 2013. In addition, the results of science achievement from 2010 to 2013 can be used to define the students' academic achievement level characteristics and provide students can with report cards that will provide basic aid and information for students, teachers, and school administrators. Through these results, experts were engaged and provided a way to give suggestions on educational policy through consultations.

Third, in-depth analysis of the student responses should be conducted as follow-up studies. The current NAEA distinguishes each student's achievement level, and by using the representative items of each level of the achievement standard of a student's evaluation results, teaching and learning directions can be suggested accordingly. However, because many of the items are in the Above Advanced level, not much information can be provided to students in the Proficient and Basic level. One of the main reasons for this is the decline in the academic ability of the students. However, limitations in the current research methods make it difficult to determine the reasons that students have difficulty answering items correctly. Therefore, further study into how a student correctly or incorrectly responds to a specific item in a particular achievement level can help us recommend suitable teaching and learning methods for that student.

Fourth, student profiles should be analyzed in order to create more specific suggestions for educators and educational policy-makers. This study has defined the characteristics of students' achievement levels by using the representative items of NAEA. However, the actual characteristics of students themselves have not been analyzed. Therefore, further study needs to be conducted by grouping students into more specific segments. Students from each achievement level's characteristics, such as gender, social class, learning ability, region, and type of school (private vs public), should be described in more detail.

Finally, Korea's high level of success in international assessment in science has led to great interest in science education in Korea. However, the research explaining the reasons behind Korea's high performance has been insufficient. Many countries administer national assessments measuring the academic achievement levels of their students. Analysis of the relevant results and data from these assessments provides valuable policy implications. Korea actively focuses on identifying the

students whose NAEA level is Below Basic and has implemented a "policy of improving the academic abilities of low-achieving students," a policy that provides financial and administrative support for schools with Below Basic-level students. This policy also includes learning and teaching methods that are customized for each school's unique characteristics and circumstances. It is widely regarded that Korea has been able to remain academically competitive internationally because of such policy initiatives. This research is an ideal example of how a national-level academic assessment can contribute to establishing data-driven policy-making as well as evidence-based teaching and learning methods. These results can also be used practically by both domestic and the global science education community to understand Korea's national science curriculum as well as the level of Korean students' science achievement.

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