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The Study on the Misconceptions of Digestion Based on the Analysis of Constructed Response Items in the National Assessment of Educational Achievement (NAEA)

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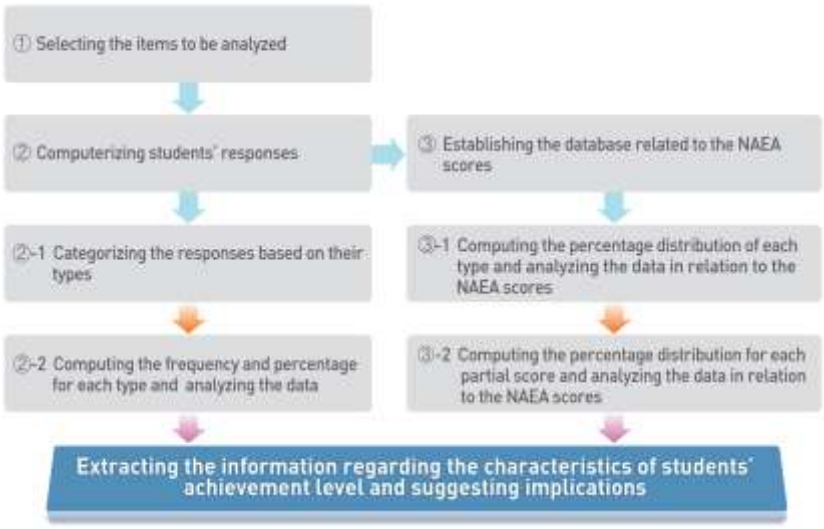
Abstract
In Korea, National Assessment of Educational Achievement (NAEA) is administered on a yearly basis. Its results are analyzed to examine the changes in students' academic achievement, to ensure the quality of the national curriculum and to improve teaching and learning methods.
In this study, a statistically significant sample of around 7,500 students was selected and analyzed in relation to the NAEA scores. This study focused on the answers students gave on the constructed response items related to digestion in the content area 'life' in middle school science. The students' answers were classified, and the frequency distribution and percentage for each answer classification based on their test scores were provided. The frequency and percentage of students' misconceptions regarding digestion were also calculated.
The study results showed the characteristics of the students' academic achievement, which is difficult to be identified from the descriptive statistics data (the percentage of correct answers, the percentage distribution of partial scores and etc.). For example, while the students with high achievement level were able to understand digestion as a change in size at the molecular level and relate it to absorption, the students with low achievement level understood digestion only as a necessary process for absorption or didn't understand digestion itself. In addition, the percentage for each classification of misconceptions varied according to their achievement level. The students with high achievement level were likely to misunderstand digestion as a way of obtaining nutrients or energy to support life or as something related to metabolism. On the other hand, the students with low achievement level had misconceptions that relate digestion to daily life; they had a tendency to misunderstand digestion as a means of preventing diseases or consuming more food.
This study is significant as the number of students' answers to the constructed response items analyzed was great enough to estimate the characteristics of the whole student population. Thus, the results of this study have implications for improving the national science curriculum and supporting customized teaching and learning methods suitable for each achievement level.

1. Introduction
In Korea, the NAEA is implemented in order to obtain the data for the improvement of the curriculum as well as teaching and learning methodology by determining the extent of students' achievement in relation to the educational aims of the curriculum. The data for the improvement of the curriculum and teaching and learning methodology can be obtained by analyzing students' level of understanding of general concepts or principles that the questions aim to assess and their level of behavior concerning their application of the acquired knowledge, in relation to the assessment results.
As constructed response items in NAEA can elicit various responses, they allow a multi-perspective analysis and suggest more meaningful implications compared to multiple-choice items. For such purpose, the responses to the constructed response items from five subjects (Korean language, social studies, mathematics, science, and English) were selected and analyzed in 2014. A total of around 7,500 responses to the constructed response items was analyzed. From the results of the analysis, one example of the analysis of a constructed response item of science is discussed in this study.
The selected science question measures students' ability to present the circumstances of an experiment and reach a conclusion as well as the ability to explain the necessity of digestion based on the experimental findings. The responses to the science question were classified into different types and the frequency and the score distribution for each type were computed for the analysis. In addition, the misconceptions presented in the responses were categorized into different types, and the frequency and the score distribution for each type of misconceptions were computed for the analysis.

2. Method

The constructed response item was analyzed in the following steps.

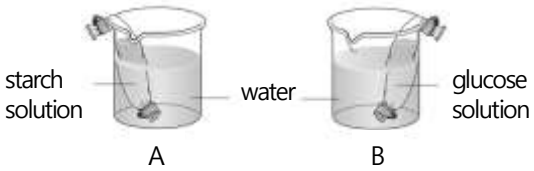


[Fig. 1] Analysis procedure of constructed response item

3. Construction of the Item

[Item 6] Following is the experiment to find out why food has to be digested in the body.

<Procedure>
(a) Prepare two cellophane tubes, and pick up one end with a clamp to prevent leakage of the contents.
(b) Pour 10mL of starch solution and 10mL of glucose solution into each cellophane tube, and pick up the other end of the tube with the clamp. And then put each cellophane tube into the beaker containing water.



(c) After around 20 minutes, pour some water contained in beaker 'A' into test tube 'a' to observe iodine reaction. At the same time pour some water contained in beaker 'B' into test tube 'b' to observe Benedict's reaction.
<Results>
The color of test tube 'a' changed, but the color of test tube 'a' did not change.

(1) Write the name of appropriate material for ( ) below.

The results of this experiment show that ( ) can pass through a cellophane tube.

(2) Based on the results of this experiment, write the reason that food has to be digested in the body.

4. Results

4-1. The percentage of correct answers

Item 6-(1): 53.50%, Item 6-(2): 20.91%

4-2. Response types

In order to devise a draft of response types, a portion (10%) of the responses were analyzed preliminarily and classified based on their characteristics. <Table1> and <Table2> show the response types for each sub-item. For the sub-item 6-(1), the response types were classified based on whether or not students were able to reach a conclusion by interpreting the experimental findings.

<Table 1> Response types: Item 6-(1)

Type	Characteristics of type	Examples of answers
Type1-1(CC)	·Reaching appropriate conclusions by understanding the experimental procedure and interpreting the experimental findings	·glucose
Type 1-2(IC)	· Failing to reach appropriate conclusions due to lack of understanding of the experimental procedure and misinterpretation of the experimental findings	·starch, carbohydrate ·water
Type 1-3(UU)	· Failing to understand the experiment and to reach appropriate conclusions	·Benedict solution, beaker, test tube ·nutrient, solution, particle, blood, heat
Type 1-4(NS)	· Nonsense symbols, numbers etc.	·2, R, you?, X, there
Type 1-5(NR)	·No response	

(CC: Correct Conclusion, IC: Incorrect Conclusion, UU: Ununderstanding, NS: Nonsense, NR: No Response)

For 6-(2), the response types were classified based on whether or not they include the elements (a) and (b) of the sample answer as well as the misconceptions.

(a): Food needs to be broken down into smaller particles. (b): Then it can be absorbed into small intestine.

<Table 2> Response types: Item 6-(2)

Type	Sub type	Elements of answers	Examples of answers
Type2-1 (DA)	DA-1	(a), (b), and no misconception.	·Because a big nutrient such as starch needs to be broken down into small particles for it to be absorbed into small intestines.
	DA-2	(a), (b) and misconceptions that are not related to (a) or (b)	·None
Type2-2 (D)	D-1	(a)	·Because starch is broken down into glucose.
	D-2	(a), and misconceptions that are not related to (a)	·Starch does not get digested because of its big particle size. Therefore starch needs to be broken down into glucose to be digested.
Type2-3 (A)	A-1	(b)	·For nutrients to be absorbed, they have to be digested first.
	A-2	(b), and misconceptions that are not related to (b)	·None
Type2-4(NDA)	-	Misconceptions only ((a), and (b) are not included)	·If food is not digested, it gets accumulated in the body, possibly causing various kinds of disease.
Type2-5(NS)	-	Nonsense symbols and numbers	· I don't know. · Hello.
Type2-6(NR)	-	No response	

*Among the response types, DA-2 and A-2 were omitted from the analysis as they were not presented in students' actual responses.

4-4. Types of Misconceptions concerning digestion and absorption

<Table 3> shows the types of misconceptions presented in the responses to item 6-(2).

<Table 3> Types of Misconception in item 6-(2)

Type	Sub type	Contents of misconception	Examples
M1 Misconceptions of digestion	M11	Understanding digestion as a way of preventing disease or maintaining health	· If starch is not digested and glucose is passed into body, it may cause a diabetes.
	M12	Understanding digestion as a process of excreting or removing waste matter	· To filter waste matter To prevent getting reabsorbed from urine
	M13	Understanding digestion as the synthesis of substances	· Because glucose needs to be synthesized.
	M14	Understanding digestion as the breakdown of glucose	·Because glucose needs to be broken down.

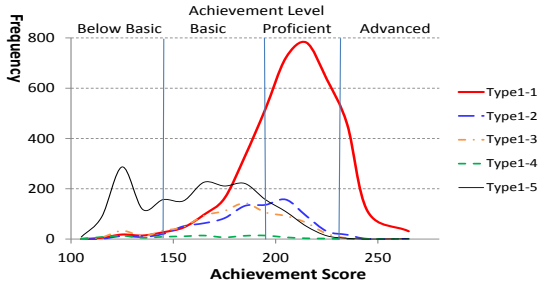
Type	Sub type	Contents of misconception	Examples
	M15	Understanding that digestion of food depends on the particle size of nutrients in the food	·As starch is difficult to digest because of its large size. ·As small particles are easily digested.
	M16	Understanding that digestion reduces the body weight	·If food is not digested, we gain weight.
M2 Misconceptions of the need of digestion	M21	Understanding digestion as a process of excretion for consumption of more food or excretion of substances in the intestine	·If food is not digested, the intestine may get blocked by the food that we eat.
	M22	Understanding digestion as a process of securing nutrients by separating and extracting them from food	·Because nutrients have to be separated to be absorbed in our body.
	M23	Understanding digestion as a process of getting or releasing energy source	·By getting energy, starch can change into substances that can be saved in our inner body to prevent loss.
	M24	Understanding digestion as a process of changing insoluble materials into soluble materials	·Digestion is needed because starch is not soluble in water.
M3 Misconceptions of absorption	M31	Understanding that absorption can take place if size of molecule is large or if osmosis occurs	·Starch that is large in size is absorbed into body, and glucose that is small moves through blood.
	M32	Understanding absorption as a process of emitting nutrients from the body	·Because large particles such as starch can't get emitted from body, the particles need to be broken down to get digested.
M4 Etc	M41	Other contents that are irrelevant to the experiment or misconceptions	·As the air passes into body, food can be digested. ·Because starch leads to evaporation

4-5. Frequency distribution and percentage distribution of response types based on the scores

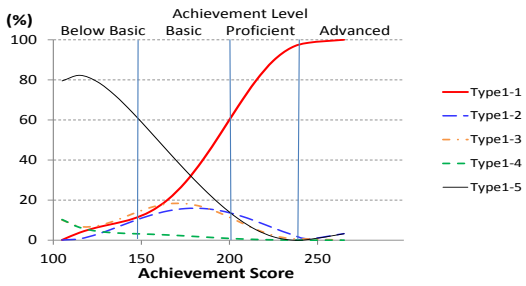
The frequency distribution and percentage distribution of the answer types of sub-item 6-(1) are shown in following [Fig.2], [Fig.3], and those of item 6-(2) are shown in following [Fig.4], [Fig.5].

For Item 6-(1), the frequency of response types was presented in the following order: 1-1>1-2>1-3.

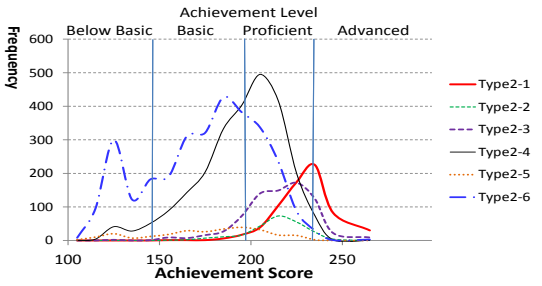
For Item 6-(2), The order of frequency types is as follows: 2-4>2-3>2-1>2-5>2-2.



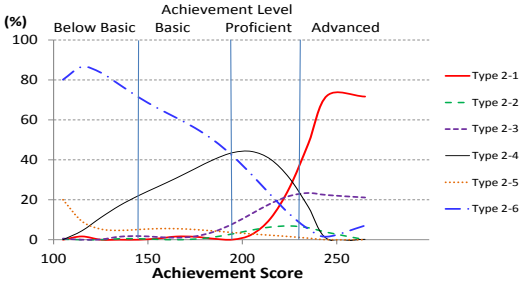
[Fig.2]The frequency distribution of the types in 6-(1)



[Fig.3]The percentage distribution of the types in 6-(1)



[Fig.4]The frequency distribution of the types in 6-(2)

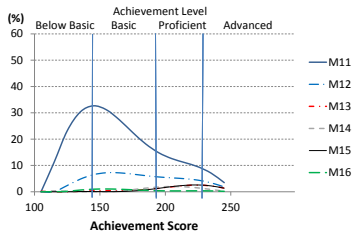


[Fig.5]The percentage distribution of the types in 6-(2)

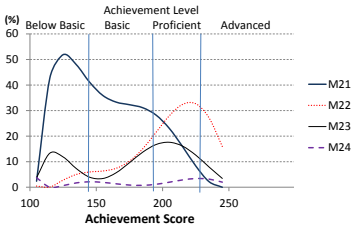
4-6. Misconception

- The percentage of the types of misconceptions based on the NAEA scores for responses to the sub-item 6-(2) is presented in [Fig. 6]-[Fig.8].

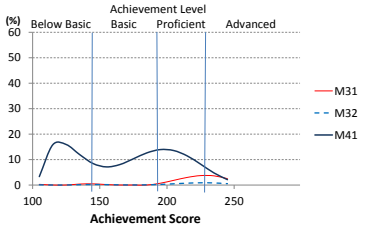
- The frequency of types of misconceptions was shown in the order of M2>M1>M3, and among the subtypes, the frequency of M11, M21~ M23 was high while M13~M15, M24, M31, and M32 was low.
- While a large number of students with Advanced and Proficient achievement levels presented M22, and M23, a large number of students with low achievement level presented M21.
- Although the low-frequency misconceptions types M13~M15, M24, M31, and M32, which are related to the synthesis, breakdown, size of particles and etc., was low in frequency, they were mostly presented by students with high achievement level.



[Fig.6]The percentage distribution of M1



[Fig.7]The percentage distribution of M2



[Fig. 8]The percentage distribution of M3

5. Discussion and Conclusion

5-1. Students' understanding of digestion differs according to their achievement level.

- Based on the achievement level, type 2-1 was presented by students with high achievement level, and type 2-3 was presented by students with average achievement level. Students with low achievement level displayed high rate of no response and presented low frequency of type 2-1, 2-2, and 2-3.
- Such result indicates that while students with high achievement level are able to understand digestion as the changes in size at the particle level and relate digestion with absorption, students with low achievement level understand digestion only as a necessary process for absorption or fail to understand the concept of digestion.

5-2. There were many responses explaining the necessity of digestion without the basis of experimental findings.

- A large number of students with average achievement level presented Type 2-4 for item 6-(2), and a relatively large number of students with high achievement level as well as low achievement level also presented such type of responses.
- This result indicates a number of students tend to explain the necessity of digestion based on their prior knowledge instead of basing their responses on the experimental findings.

5-3. The types of major misconceptions and the percentage of each type differed based on the achievement level.

- The common misconceptions of students with high achievement level included their misunderstanding of digestion as a way of obtaining nutrients or energy to support life (M22, M23) or linking it with metabolism.
- Students with low achievement level had misconceptions concerning daily life. For example, they tended to misunderstand digestion as a means of preventing disease or consuming more food.

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