Journal of the Korean Chemical Society
2016, *Vol. 60, No. 6*
Printed in the Republic of Korea
http://dx.doi.org/10.5012/jkcs.2016.60.6.415

The Characteristics of "States of Matter" Concept Attributes of 3rd to 6th Grade Elementary School Students

Jung-In Choi and Seoung-Hey Paik[†,*]
Incheon Garim Elementary School, Incheon 22820, Korea.
[†]*Department of Chemistry Education, Korea National University of Education, Cheongju 28173, Korea.*
[*]*E-mail: shpaik@knue.ac.kr*
(Received July 12, 2016; Accepted September 23, 2016)

ABSTRACT. This study analyzed the attributes of the conceptions of 3rd to 6th grade elementary school students on three states of matter and investigated the characteristics of the classified results of various examples of matter by grades. Through discussion activities, we confirmed the stabilization of conception attributions. For this study, 113 participants from two 3rd to 6th grade elementary school classes were selected. The concentration analysis (C-factor) and normalized gain (G-factor) of the conceptions for the quantitative analysis of the conception changes were used. The elementary school students retained different percentages of the attributes for states of matter. The characteristic of the grades were different between the 3rd grade and other grades. Based on these results, we pointed out the problems with the present teaching methods in science textbooks and stated the advantages of the effects of the representation of mixtures.

Key words: State of matter, Classification, Elementary school students, Attributes of conceptions

INTRODUCTION

An important goal of scientific education is to foster students with scientific literacy.[1] Matter and energy are the most fundamental concepts in science,[2,3] and science educators expect students to look at nature using scientific concepts and to be equipped with scientific literacy so that students are capable of solving scientific problems through school education.

In the case of Korea, learning of matter from a macroscopic point of view starts from the 3rd grade in elementary school, after which the transition is made to learning to understand matter from a microscopic point of view in middle school and high school. If successful learning is carried out, students should be able to formulate scientific concepts of matter, see for themselves how the concepts have been formulated, and resolve new problems through the formulated concepts.

Accordingly, appropriate and effective curriculum making, teaching material preparation, and teaching method selection are very important for the attainment of educational goals. Before that however, students' knowledge of the concept of states of matter should be confirmed first. Although a number of studies have been carried out in relation to this at home and abroad, their educational effects are doubtful.[3–10] For example, because students think that matter can be seen or touched,[4] they fail to perceive gas as a matter or perceive liquid as something similar to water.[5,6] In particular, misconceptions about gas, which cannot be perceived through the senses, have been reported in the biggest number of studies.[7–9] Kim, S. K. *et al.*[10] explained that although middle school students have been taught to develop their attitude toward matter from a microscopic point of view, they attempt to differentiate states of matter from a macroscopic point of view. Their classification criteria from the microscopic and macroscopic points of view lack consistency, and they make the mistake of applying different classification criteria depending on the situation.

However, as the microscopic point of view is introduced after the middle school curriculum, this difficulty of students is hard to generalize as a problem of elementary school students. This is because the alternative conceptions used by elementary school students cannot be sufficiently explained as discontinuity of transition from a macroscopic point of view to a microscopic point of view, as elementary school students learn classification of matter with a focus on explanation from a macroscopic point of view in the current curriculum. Accordingly, we need to thoroughly look into the understanding of elementary students of matter from a macroscopic point of view.

For elementary school students to have a macroscopic point of view when scientifically explaining the matter of the natural world, they have to be equipped with a reasonable explanation system that can explain individual cases.

The explanation system for the three states of matter is acquired through a method called classification. Students understand common properties of matter through the classification process. A concept formed in this way provides the criterion that can be used to classify other matter.[11] The concepts of solid, liquid and gas, which are the three states of matter, can also be said to be acquired through classification based on the similarity of the phenomenon in which each concept comes into view.[12] Accordingly, we need to check what concept attributes of matter students have and how they connect the attributes as classification criteria to individual cases. Attainment of learning objectives, that is, acquisition of scientific concepts, can be confirmed through the act of connecting individual cases to attributes of concepts, and if students experience difficulties in this process, the learning process of correcting or supplementing attributes that form scientific concepts is required. A small group discussion is a means of promoting such a conceptual change, and students will establish the concept attributes of the state of matter most stable for them through small group discussion. Based on such an assumption, in this study, the following study assignments have been established:

First, we check the aspects of concept application through the features of the concept attributes of 3rd to 6th grade elementary school students and their activities of classifying matter.

Second, we check the stable concept attributes that students established through small group discussion with other students. Through this, we intend to check whether there is any difference between the "states of matter" concept attribute across each grade and analyze differences with the scientific concept attributes presented in the science textbook. Through such an analysis, we intend to propose a change in the method of proposing the "states of matter" concept attribute presented in the current scientific textbook.

METHOD OF STUDY

Object of study

This study was carried out with 120 students from two classes across the 3rd to 6th grades in an elementary school located in metropolitan city A. A total of 113 respondents were the objects of final analysis, as 7 respondents whose responses lacked consistency were excluded. As a result of the diagnostic examination carried out by metropolitan city A, the object students showed good basic academic ability with no poor subjects learning. As the sample sizes were small, because the numbers of the 3rd, 4th, 5th and 6th grade students were 30, 25, 27, and 31 respectively, and there were limitations to the convenience sampling method, care should be taken in generalizing the results of this study.

Instrument

The instrument was developed by correcting and supplementing the questions used to check the concept of "states of matter" in preceding studies.[12,14,15] The number of questions in the questionnaire was 23, among which questions no. 1, 2, and 3 asked the students to describe the definitions of solid, liquid, and gas respectively. In the 20 subsequent questions, the specific example of matter was considered, and the students were asked to select one matter from solid, liquid, gas, or to select "cannot be classified," and explain the reason for their choice. The questionnaires were answered twice before and after the small group discussion activity.

The examples used for the classification activity numbered 20 and were selected by considering the functions of examples in preceding studies.[12,15] Ice, water, air, and oxygen were selected as the examples of explanation that carry out the functions of empirical cognition, grasping of attributes, verification, etc., and eraser, soft fabric, fruit juice, flour, glass, muddy water, and lava were selected as examples of reinforcement that carry out the functions of identification, comparison, and assumption. Cotton, mist, jelly, steam, cloud, pudding, cookie dough, smoke, and person were selected as the examples of clarification that carry out the functions of expansion and contrast. In particular, the examples of clarification out of general attributes were used to induce cognitive conflicts[12] of the students. The validity of the questionnaire was secured by letting one science educationalist and two teachers who majored in elementary school science cross-review it.

Study procedure and data analysis

The students' ex-ante concept of states of matter was checked through an advance questionnaire in which the three states of matter were defined, and diverse examples were classified into the three states of matter. Later, a discussion activity was conducted in small groups comprised of 3 to 5 persons. The participants were provided with the chance to correct their concepts of classification criteria for matter by discussing their experiences in prior classification activities with group members during the discussion activity. Next, students' ex-post concept of states of matter was checked by administering an ex-post questionnaire in which the three states of matter were defined again, and diverse examples were classified into the three states of matter.

Students were asked to respond to the questions asking for the definitions of states of matter with descriptive answers. Additionally, to analyze the attributes of the concepts

***Table* 1.** Criteria of attributes of matter status for the analysis of students' responses

Criteria of attributes	Examples
Changes in the shape and volume (a)	Solid: Shape is not changed according to the shape of container.
Degree of hardness and fluidity (b)	Solid: It's hard. Liquid: Liquid flows freely.
Perception of existence (c)	Solid: It can be touched. Gas: Gas is invisible or cannot grasp.
Prototypical examples (d)	Liquid: Liquid looks like water.
Position (e)	Gas: The gas may be floating in the air.

uncovered in the definition of each state of matter stated by the students, an attribute criterion for the concept of matter from a macroscopic point of view was prepared by categorizing preceding studies[10,12] and the answers to the questionnaire (*Table* 1).

The detailed concept attributes from a macroscopic point of view based on phenomena include "change in shape and volume," "degree of hardness and fluidity," "whether the substance is perceived or not," "prototype," and "position." The difference from the concept attributes presented in the preceding studies[10,12] is as follows: first, "whether a form exists or not" is corrected to "whether the substance is perceived or not." When we looked into the answers of the students, it could be seen that they determined the state based on the criterion of whether the solid or gas is touchable or visible. Such a criterion is related to the issue of whether the object can be perceived using a sensory organ or not, that is to say, whether the relevant substance is perceivable or not. The visual/tactile perception of elementary school students was a very important path to perceiving matter. Next, the "presentation of a prototype" was added as a detailed concept attribute. This was because, in some cases, a concept was defined by stating the prototype with other attributes or presenting only the prototype as the attribute of the relevant concept in the actual responses of the students. A prototype means that the most "typical" and "ideal" model is good enough to represent the relevant concept.[16] For example, water is a prototype of liquid. Lastly, in the case of gas, "position" was added as an attribute of concept. When categorizing the responses of the students, it was reflected that, in the case of gas, the students had different cognition from the state of other matter, such as "it is floating in the air," "it flies," etc. When analyzing students' response based on the above attribute criteria, if states of matter were defined using more than one attribute, the frequency was marked repeatedly on each attribute category when carrying out the descriptive statistics work. The validity of the concept attribute was verified by one science educationalist and two teachers who majored in elementary school science and, if an objection was raised when the students' answers were classified on the basis of the five concept attributes above, consistency of the analysis was increased through consultation between researchers.

In this study, to quantitatively analyze the results of the students' activities of classifying matter, the ex-ante and ex-post Ratio of Correct Answer (RCAs), G-factor, and C-factor, were used. To measure the change in the concept,[17] Hake proposed Normalized Gain (G-factor), which shows the change in the ex-ante and ex-post scores. After analyzing sample data of US college students to determine the change in the concept of physics, Hake reported that the G-factor of interactive participatory classes is significantly higher than that of traditional lecture-centric classes,[17] and besides, the G-factor of Hake is used as a scale to measure the change in the concept of subjects in fields such as physical and chemical education.[18–21] The formula used to obtain the G-factor of Hake is as follows.[17]

$$\langle G \rangle = \frac{\text{(posttest average\%) - (pretest average\%)}}{\text{100\%-(pretest average\%)}}$$

A G value of 0.7 or higher means a superior level, 0.3 to less than 0.7, an ordinary level, and the case where it is higher than 0 and lower than 0.3 means a low level change in the concept.[17] In this study, the pretest average percentage is the RCA of the ex-ante classification result, and the posttest average percentage indicates the RCA of the ex-post classification result.

Along with the G-factor, the C-factor was introduced to conceptually analyze the responses of the students. The C-factor (Concentration factor) represents the concentration factor of each questionnaire in a multiple choice type question that investigates one's understanding of concepts and is defined as follows:[22]

$$C = \frac{\sqrt{m}}{\sqrt{m}-1} \times \left(\frac{\sqrt{\sum_1^m n_i^2}}{N} - \frac{1}{\sqrt{m}} \right)$$

m is the number of the responses presented in the question, N is the number of students who have responded to the question, and n_i is the number of the students who have selected the i^{th} response.

The C-factor can be used together with the RCA of each question to show the responses of the students to a question. For example, the question of which RCA and C-factor is high is the case where most of the students give the right answer to the question, and the question of which C-factor is high though the RCA is low is the case where many students give the wrong type of answer.[23] Bao and

***Table* 2.** Coding scheme for score and concentration factor

RCA	Level	Concentration factor (C)	Level
0–0.4	L	0–0.2	L
0.4–0.7	M	0.2–0.5	M
0.7–1.0	H	0.5–1.0	H

***Table* 3.** Students' responses patterns and interpretations of the patterns

Response model	Response pattern	Interpretation of the patterns
One-peak	HH	One correct concept system
	LH	One dominant incorrect concept system
Two-peak	LM	Two incorrect concept systems
	MM	Two concept systems (one correct and one incorrect)
Non-peak	LL	Three or more concept systems represented somewhat evenly

Redish, who proposed the C-factor, set class intervals of the RCA and the C-factor (*Table* 2), combinations of which were used to classify the answers to the questions into 3 models and 5 types (*Table* 3).[22]

The type HH, in which both the RCA and C-factor are high, is the case where the responses of the respondent are concentrated on a correct answer, and the type LH, in which the C-factor is high though the RCA is low is the case where the responses are concentrated on a certain incorrect answer.[23] In particular, the type LH is meaningful for understanding alternative conceptions by students. As the types HH and LH are cases where the responses were concentrated on one answer, they fall under the one-peak model.

Because the case where the C-factor is low is the case where different answers are evenly distributed, as the RCA cannot but be low, it belongs to the type LL of a Non-Peak model. In this case, it can be seen that the students do not show any specific misconception but have selected a response at random as the question itself is difficult.[23]

Though the classification result of 20 types of actual examples such as cookie dough were analyzed to check whether the students' concept of the three states of matter effectively works in classifying the examples, only 10 types of examples with a low RCA among them were selected and presented in the study results. The detailed descriptive statistics result of the students' classification activities for states of matter is presented in the appendix. The attributes of the students' concept of matter and the classification result of states of matter were analyzed using the method mentioned above and, to obtain in-depth information about the attributes of concepts possessed by the students and about their classification activities, the students were interviewed, the contents of the interview were transcribed after being recorded, and meaningful content was extracted.

STUDY RESULTS AND DISCUSSION

Change in the attribute recognition of solid concepts

The results of investigating 3rd to 6th grade elementary school students' concept attributes before and after the discussion activity for solid concepts is shown in *Table* 4.

Unusually, the percentage of 3rd grade students who perceived solids with "constancy of shape and volume," which is the concept attribute of solid presented in the current science curriculum, was the highest both before and after the discussion activity. This may be because the definition of solid is presented in the unit "Our Life and Matter" in the first semester of the third grade. However, in the case of the other grades, the percentage of students who perceived solid using attributes such as "hardness" or "perception of substance" was higher. The students returned to the concept attribute presented in the current curriculum only after they exchanged opinions with other students through the discussion. However, such a percentage was also as small as 51.7% of the total. Accordingly, it can be seen that about half of the students perceive a solid using other concept attributes even after the cognitive conflict.

Though "hardness," "firmness," etc., which are classified as alternative conceptions, are the major criteria used by children at ages 7 to 12 to classify solids,[5,24] such concept attributes cause under-generalization when classifying powdery matter as a liquid.[25] Additionally, "perception of substance," which possessed by the biggest number of 5th

***Table* 4.** The differences of students' attributes of solid conception by grade in pre- and post-discussions

Grade	Changes in the shape and volume		The degree of hardness and fluidity		The perception of existence		The presentation of prototypical examples		Total	
	Pre	post	Pre	Post	Pre	Post	Pre	post	Pre	Post
3	27(60.0)	26(68.4)	3(6.7)	0(0.0)	14(31.1)	12(31.6)	1(2.2)	0(0.0)	45(100)	38(100)
4	8(27.6)	21(46.7)	14(48.3)	16(35.6)	4(13.8)	8(17.7)	3(10.3)	0(0.0)	29(100)	45(100)
5	12(29.3)	19(50.0)	12(29.3)	7(18.4)	15(36.6)	12(31.6)	2(4.8)	0(0.0)	41(100)	38(100)
6	13(28.9)	26(45.6)	11(24.4)	8(14.0)	18(40.0)	23(40.4)	3(6.7)	0(0.0)	45(100)	57(100)
Total	60(37.5)	92(51.7)	40(25.0)	31(17.4)	51(31.9)	55(30.9)	9(5.6)	0(0.0)	160(100)	178(100)

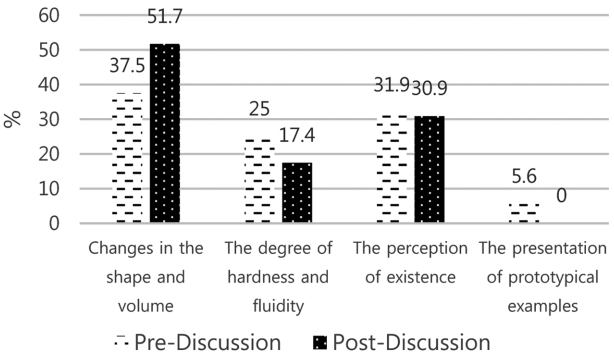

***Figure* 1.** The changes of students' attributes of solid conception before and after discussion.

and 6th grade students before the discussion activity, did not agree with the general view that the more children grow, the more complex the classification system they will accept.[13] This is because this attribute of solid concepts is at a very elementary level in comparison to other attributes.

Such a concept attribute does not change even after the discussion activity showing that it is very firm. It can also be seen in *Fig*. 1, which presents a change in the concept before and after the discussion activity with the percentages of the total number of students of all grades. However, as a whole, it can be confirmed that the most stable attribute of solid concept is the attribute of "constancy of shape and volume" presented in the current science curriculum.

The solid matter whose RCA in the classification result of states of matter before and after the discussion activity was low included four types of matter: smoke, flour, soft fabric, and cotton. The RCAs of the students, C-factor, types of students' answers, and G-factor before and after the discussion activity are put in order and presented in *Table* 5. As the RCA of smoke was 0% and its C-factor was as high as 0.86, it showed a response pattern of LH. This is because the students highly tend to classify smoke as a gas, not a solid. Further, as the G-factor was 0 even after the discussion, the students were completely unable to connect smoke with the concept attribute of solid.

When we students who classified smoke as a gas why they did so, they answered "because it is floating in the air" or "because it looks like a gas," and they failed to focus on the solid particles that the smoke consisted of. "It looks like a gas," "it cannot be touched," etc., show the attributes of "perception of substance," which induces over-generalization. Further, the process of classifying smoke as a gas using the attribute "position," such as "because it is floating in the air," also falls under over-generalization. To enable students to classify smoke as a solid, students should be taught to connect a solid concept attribute to a relevant phenomenon.

After discussion activity, as the C-factor for the state classification of smoke went down to 0.48, the type changed from LH to LM. While the students classified smoke as a gas before the discussion, they came to have an opinion that smoke cannot be classified as a gas after the discussion. This is because they in the process of the discussion, they found that smoke cannot be categorized as "invisible," which is one of the concept attributes of gas.

Student A: Isn't smoke a gas? It floats in the air, where it exists, and soon disappears.
Students B: By the way, if it is a gas, it should be invisible. But it is visible.
Student C: You are right. However, it cannot be grasped by hand and moves like a gas.
Student B: But, it cannot be said to be a gas as it is visible. And some smoke is gray, and some is black. Aren't the colors different?
Student A: You are right. What is it? Does it mean that it is mixed with something?
Student C: Yeah. It looks like a gas, but we cannot say it is a gas. I don't know.

In the case of flour, as the type was shown to be MM with an RCA of 0.63 and C-factor of 0.38, it can be said that the students responded by concentrating on two answers. Though the trend of the students classifying flour as a solid was strong, there were also opinions that its state of matter cannot be determined. In particular, the 3rd grade students were most confused about the classification, and 33.3% of the students had difficulty in determining the state of flour. Though the students learnt about solid matter made of powder such as sugar or salt from the textbook of the 3rd grade in

***Table* 5.** Item analysis by RCA, C-factor, G-factor, and pattern of response of solid conception

Item	Concept	Pre-test		Pattern of level	Post-test		Pattern of level	G-factor
		RCA	C-factor		RCA	C-factor		
Smoke	Solid	0.00	0.86	LH	0.00	0.48	LM	0.00
Wheat flour	Solid	0.63	0.38	MM	0.85	0.72	HH	0.59
Soft fabric	Solid	0.88	0.78	HH	0.86	0.74	HH	-0.17
Cotton	Solid	0.75	0.52	HH	0.78	0.60	HH	0.13

the first semester, they had difficulty in perceiving powdery matter as a solid depending on the material. This is because, when compared with salt or sugar, flour is very soft and does not fit the attribute of solid that it is hard.

After the discussion activity, the G-factor of the students was very big, showing a value of 0.59. As the RCA was improved to 0.85, and the C-factor also increased to 0.72, the response type changed from MM to HH. This is because many students connected the grain of flour to a solid concept attribute in the process of the discussion.

Student E: Flour looks like a gas. This is because flour looks like smoke, as it is too fine.
Student F: By the way, flour looks like a gas if it is floating in the air, but it looks like a solid if it is gathered.
Student G: I think it is a liquid! The shape changes with the container, and it is not grasped by hand, and it flows.
Student H: No. If you look at flour, small grains are contained in it. As the grains are solids, flour is a solid.
Student E: But, it is not hard and does not have a fixed shape.
Student H: The small grains are hard and do not change.
Students E, F and G: Oh, that's right! Then, let's say that flour is solid.

However, as the percentage of the students who failed to directly connect flour to the solid concept attribute was high before such a discussion activity, an educational plan is required to foster the ability of the students to generalize and apply the solid concept attribute.

Differently from smoke and flour, in the case of soft fabric and cotton, the percentage of students perceiving them as solids was high both before and after the discussion activity. Accordingly, the type was shown to be HH, and the G-factor was relatively low. This is because the concept of the question that shows a high RCA in the pretest is not easy to change.[23] In light of such a result, though cotton or fabric looks soft or its shape keeps changing, the attributes of fabric and cotton are perceived to be closer to the attributes of solids than the attributes of liquids or gases possessed by the students. However, the issue of how fabric and cotton are connected specifically to the typical concept attribute of solid such as "hardness" or "fixed shape" is not clear. In the case of fabric in particular, the RCA after the discussion somewhat decreased, making the G-factor show a negative value. That is, a little change in the concept of the students took place in the direction of not classifying fabric as a solid, as the solid concept attribute that it is hard and the softness of fabric did not agree with each other. Accordingly, in the case of soft fabric and cotton too, an educational plan is required to be considered so that the direct connection to the typical solid concept attribute possessed by students can be achieved.

Change in the attribute recognition of liquid concept

The result of investigating the liquid state concept of 3rd to 6th grade elementary school students is shown in *Table* 6.

Similarly to solid, in the case of the 3rd grade students who dealt with the concept of liquid in the school curriculum, the percentage of students perceiving liquid using the attribute "though the shape changes, the volume is constant" was the highest, showing a value of 58.9 % before the discussion activity. However, the attribute of liquid concept failed to increase with grade, and the percentage of perceiving liquid using the attribute of "fluidity" was much higher from 4th to 6th grade, which lasted even after the discussion.

Additionally, differently from solid, the percentage of students perceiving liquid using a prototype such as "watery" was somewhat high before the discussion activity. This result agrees with the results of the preceding study[5] that students express liquid using a prototypical matter such as water. In case the state of liquid is established introducing a "prototype" like this, under-generalization may be caused where a liquid with an attribute is very different from that of water that cannot be perceived as a liquid.[25] As perception of prototypical concept attribute is at a very elementary step, such a result means that the education method presented in the current science curriculum is not effective in perceiving the liquid concept attribute of the students. Accordingly, the school education method is required to be changed in such

***Table* 6.** The differences in students' attributes of liquid conception by grade between pre- and post-discussions

Grade	Changes in the shape and volume		The degree of hardness and fluidity		The perception of existence		The presentation of prototypical examples		Total	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
3	33(58.9)	21(50.0)	13(23.2)	17(40.5)	6(10.7)	4(9.5)	4(7.1)	0(0.0)	56(100)	42(100)
4	8(23.5)	17(50.0)	14(41.2)	17(50.0)	0(0.0)	0(0.0)	12(35.3)	0(0.0)	34(100)	34(100)
5	9(28.1)	11(32.4)	20(62.5)	23(67.6)	0(0.0)	0(0.0)	3(9.4)	0(0.0)	32(100)	34(100)
6	11(25.6)	26(44.8)	20(46.5)	27(46.6)	3(7.0)	5(8.6)	9(20.9)	0(0.0)	43(100)	58(100)
Total	61(37.0)	75(44.6)	67(40.6)	84(50.0)	9(5.5)	9(5.4)	28(16.9)	0(0.0)	165(100)	168(100)

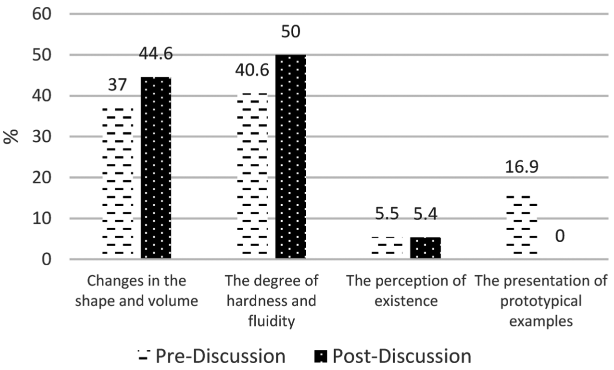

***Figure* 2.** The changes of students' attributes of liquid conception before and after discussion.

a way that the concept attribute of liquid can be stably perceived by students.

The results of putting together the change in the liquid concept attribute of the students before and after the discussion is as shown in *Fig*. 2. "Fluidity" accounted for the biggest percentage among the liquid concept attributes of the students both before and after the discussion, and it can be seen that prototypical thoughts disappear in the process of stabilization of the liquid concept attribute through the discussion activity.

The RCAs of the students, C-factors, response types of students, and the G-factors before and after the discussion activity for matter classified as a liquid in the classification activity included in the questionnaire are put together and presented in *Table* 7.

The students were shown to experience difficulties in classifying mist, cloud, and steam as liquid matter. The RCAs of mist, cloud, and steam were very low, showing values of 0.07, 0.08, and 0.12 respectively, and the C-factors were somewhat high, showing values of 0.76, 0.62, and 0.60 respectively. That is, the percentage of students perceiving these materials as a gas was very high.

Researcher: Is mist a solid, liquid, or gas?
Student B: It is a gas.
Researcher: Why do you think so?
Student B: First, mist cannot be caught and is floating in the air. It cannot be caught but can be felt. Isn't such a thing a gas?

As can be seen from the interview, students had a high tendency of thinking that mist, cloud, or steam was an example that better fit the concept attributes of gas such as "floating in the air" or "cannot be caught." In particular, the students thought that the three examples did not well fit with "fluidity," which is a major attribute of the liquid concept. The thought process of the students for classification of clouds was also the same.

Student C: Cloud is a gas. It gives a gas-like feeling.
Researcher: What is the gas-like feeling?
Student C: Well, something that is invisible and floating in the air. Though cloud is visible, it seems to be a gas, not a solid or a liquid.

Similar to the cases of mist and cloud, in the case of steam, the students also showed the characteristic of overgeneralizing the gas concept based on the observation phenomenon that "it is in the air" without paying attention to the liquid grains that the matter consisted of.

In the case of mist, there was no change in the type of response after the discussion activity and the percentage of the response type LH, which classified the state of mist into a gas, was still high. The RCA decreased from its value before the discussion activity, making the G-factor a negative value. This is because the opinion that one among the three states of matter could not be chosen increased when a conflict arose between the view that mist might not be a gas because of the characteristic that "it is visible" and that it might not be a liquid because it does not have "fluidity."

Student A: Isn't mist a gas? It is floating in the air.
Student B: Well, mist is visible. It is foggy.
Student C: Mist does not seem to be a gas, because gases are invisible and mist is visible. Mist also seems to be a gas as it is floating in the air.
Student D: Isn't mist made of steam? Is it then a liquid?
Student B: But, it does not flow. I do not know whether it is a liquid or a gas.

In the case of cloud and steam, the type of response changed from LH to LM after the discussion activity. The

***Table* 7.** Item analysis by RCA, C-factor, G-factor and pattern of response in liquid conception

Item	Concept	Pre-test		Pattern of level	Post-test		Pattern of level	G-factor
		RCA	C-factor		RCA	C-factor		
Mist	Liquid	0.07	0.76	LH	0.04	0.68	LH	-0.03
Cloud	Liquid	0.08	0.62	LH	0.14	0.26	LM	0.07
Steam	Liquid	0.12	0.60	LH	0.18	0.42	LM	0.07

type LM means that the question was mostly answered using two wrong responses, and this was because the opinion that the state of matter cannot be determined increased after the discussion activity. As in the following discussion examples, we can see that it was difficult for the students to accept the opinion of the students who classified cloud or steam as liquid because their perception of "fluidity" as one of the concept attributes of liquid was very strong.

Student E: Cloud is a gas! Don't you know it at a glance? It is floating in the sky.
Student F: No. It is said in a book I have read that, if we look closely at cloud, it is made of very small water droplets.
Student G: Aw, give me a break. Cloud is a gas! It cannot be grasped and those are not water droplets but air bubbles!
Student F: No. Cloud is formed by water, which goes up into the air and agglomerates. So, a cloud is made of very small water drops. Believe me!
Student H: Oh, it does not make sense. How can a cloud be a liquid? It does not flow at all! I also think that it is a gas.

In the case of flour, while the students understood that the very small grains that flour consisted of are solid during the discussion process, in the case of steam, mist, or cloud, they failed to perceive the form of the very small liquid drops that it consists of. This is because students strongly apply the attribute "fluidity" to the phenomenon when perceiving the phenomenon of liquid. Accordingly, students should be provided with the chance to learn where they can concentrate on the concept attributes of liquid other than "fluidity."

Change in the attribute recognition of gas concept

The results of investigating the concept attributes of 3rd and 6th grade elementary school students for gas are shown in *Table* 8.

With all the 3rd to 6th grade students, "whether the substance is perceived or not" for the existence of a gas accounted for the highest percentage among the concept attributes of gas before the discussion activity. Most of the students thought of gas as matter that is invisible, untouchable, and unperceivable. In contrast, the percentage of choosing the attribute "change in shape and volume," which is the definition of the school curriculum, "the state of matter where the shape changes with the container and the container is filled at all times," seemed to be low, except in elementary school 3rd grade students. This means that the effect of school education continues only with the elementary school 3rd grade students who deal with the relevant scientific concepts. In the case of the other grades, though they were more mature, the percentage of students perceiving gas using the attribute "perception of substance" was still higher than the attribute "shape and volume" even after the discussion activity. When the responses of the students were analyzed, among the 4th to 6th grade students, there was no single student who accepted the concept attribute "it fills a space" of gas in the elementary school 3rd grade textbook. This means that the concept attributes of gas presented in the textbook were not acceptable to the students.

The results of putting together the major concept attributes that form the concept of gas before and after the discussion among the 3rd to 6th grade students is shown in *Fig.* 3.

In the case of gas, the percentage of "prototype" being presented before the discussion activity was higher than the liquid or solid concept. Presentation of a prototype such as "it looks like air" is a very fundamental thought that appears when it is difficult to grasp the concept attribute, and this means that the students feel it is more difficult to grasp the concept attributes of gas than to grasp those of solid or liquid. However, this percentage disappeared after the discussion activity. This means that the method used in the current textbook to present the concept of gas to students is not effective, and a change is required to be made to enable students to more clearly judge the concept attributes of gas. In the current textbook, in some cases, the prototype "air" is equated with gas, and in many cases, explanations about various gas-related phenomena are presented without clearly focusing

***Table* 8.** The differences of students' attributes of gas conception by grade between pre- and post-discussions

Grade	Changes in the shape and volume		The degree of hardness and fluidity		The perception of existence		The presentation of prototypical examples		The position		Total	
	Pre	Post	Pre	post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
3	19(31.7)	26(68.4)	0(0.0)	0(0.0)	28(46.7)	12(31.6)	13(21.7)	0(0.0)	0(0.0)	0(0.0)	60(100.0)	38
4	1(2.9)	0(0.0)	0(0.0)	0(0.0)	21(61.8)	25(100.0)	11(32.4)	0(0.0)	1(2.9)	0(0.0)	34(100.0)	25
5	3(7.7)	8(22.9)	0(0.0)	0(0.0)	31(79.5)	23(65.7)	3(7.7)	0(0.0)	2(5.1)	4(11.4)	39(100.0)	35
6	6(11.8)	13(30.0)	0(0.0)	0(0.0)	29(56.9)	26(59.1)	13(25.5)	0(0.0)	3(5.8)	5(10.9)	51(100.0)	44
Total	29(15.8)	47(33.1)	0(0.0)	0(0.0)	109(59.2)	86(60.6)	40(21.7)	0(0.0)	6(3.3)	9(6.3)	184(100.0)	142

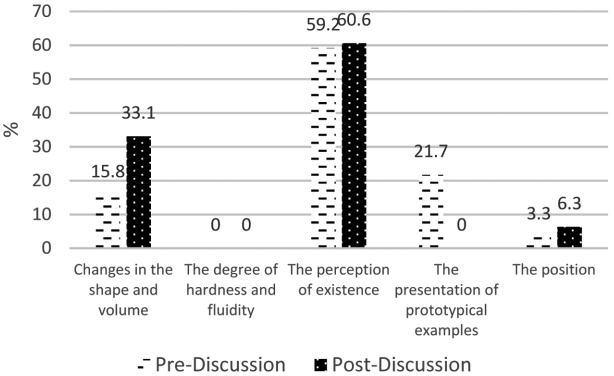

***Figure* 3.** The changes in students' attributes of gas conception before and after discussion.

on the concept attributes of gas. Accordingly, science teachers also need to understand that students have not yet properly grasped the concept attributes of gas and pay attention to learning guidance.

Additionally, differently from the awareness of the concept attributes of liquid, the concept of "fluidity" did not appear at all in the case of gas before and after the discussion activity. This too can be said to be the result of having failed to perceive fluidity due to the "invisible" attribute of gas. However, as it is very important that gas as a fluid has the attribute "fluidity" along with liquid, studies should be carried out on the content of learning that can enhance the understanding of students regarding the "fluidity" of gas. An example is the activity of letting students observe the sequence in which the lights of candles of different heights go out when a bottle in which carbon dioxide is collected is tilted to teach them that carbon dioxide is heavier than air. In such an activity, if the students are taught with the focus on the concept that, though carbon dioxide gas is invisible, it flows down like a liquid when it is poured out of the bottle, this will provide the students with a chance to perceive the attribute of the "fluidity" concept of gas.

Some students tend to possess the position perception that gas is "it is floating in the air" to differentiate gas from solid and liquid. This was apparent in the case of mist, cloud, and steam, which caused cognitive conflicts as examples of liquid. However, as it was difficult to find examples of other gases that may cause cognitive conflict, additional changes in the thoughts were not analyzed.

Stabilization of students' concept attributes

Fig. 4 shows the distribution of G-factors at different RCAs in the classification results of each question; (a) shows the G-factors at different RCAs in the classification result before the discussion activity, and (b) shows the G-factors at different RCAs in the classification result after the discussion activity. Through these figures, the stabilization levels of concept attributes for state classification of matter can be compared.

In graph (a), no special correlation between the thoughts of the students about the correct answers and G-factors can be found before the discussion. However, in graph (b), they are found to have a positive relation generally. When we look into it in detail through a correlation analysis, the coefficient of correlation (Pearson R) between the thoughts of the students about correct answers and the G-factors before the discussion was 0.091, showing almost no correlation.

However, after the concept attributes were stabilized through the discussion, the coefficient of correlation between the thoughts of the students and the G-factors was 0.584, showing a statistically significant correlation. This shows that the concept attributes of the students for state of matter cannot be sufficiently stabilized through learning in accordance with the current science curriculum.

One of the steps required to be taken to stabilize the concept attributes of states of matter is the process of elaborating on the concept attribute using an untypical example. In particular, the perception of the state of a mixture that is excluded from state classification of pure matter can help

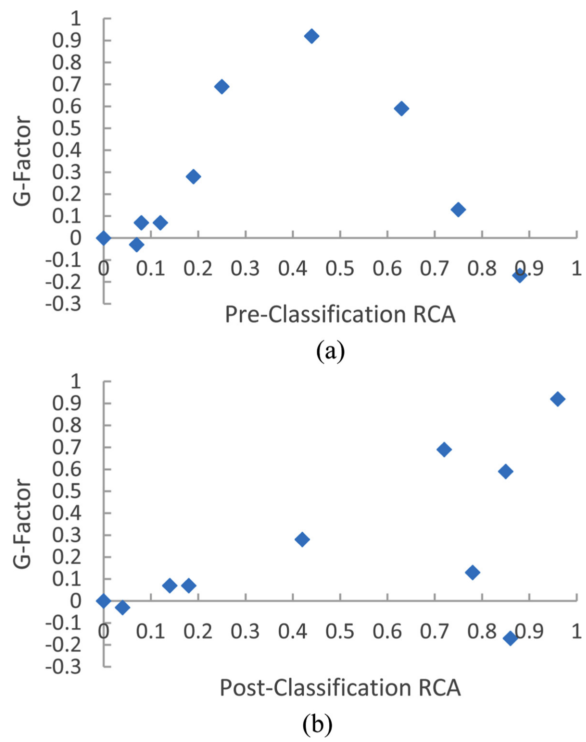

***Figure* 4.** Distribution of G-factor by RCA: (a) G-factor and pre-classification RCA, (b) G-factor and post-classification RCA.

in making clear students' concept attributes of states. However, in the current science textbook, the process of clarifying the concept attributes through the process of learning untypical example is skipped when concepts are dealt with.[26] In this study, to make clear the attributes of students' states of matter concepts, three mixtures, pudding, cookie dough and human, were presented, and a classification activity was conducted. The results are analyzed and presented in *Table* 9.

The RCA and C-factor of pudding were 0.19 and 0.46 respectively, and those of cookie dough were 0.25 and 0.32 respectively, and both were classified as the response type LM. That is, the responses were concentrated on two incorrect concept attributes, and the students classified pudding and cookie dough as solids or liquids. Most of the students classified pudding as a solid using the attributes that "it does have a fixed shape," and it does not have "fluidity."

Researcher: Is pudding a solid, liquid, or a gas?
Student E: Pudding seems to be a solid. Its shape does not change when it is left untouched. It is a solid, as the shape does not flow down or changes though it is somewhat soft like a jellied food.

However, as the attribute of solid concept is stabilized through the discussion activity, a change in the concept that pudding is not a solid has occurred. As the G-factor is not high, showing a value of 0.28, it can be seen that the attribute of the students' solid concept has not been sufficiently stabilized.

Student F: I do not know what state's feature the chubbiness of pudding is.
Student E: I know. It is a solid, but soft like a liquid.
Student G: Though the shape of pudding also changes, it is squished a little when it is put into another place. It is difficult to say if it is a solid, liquid, or gas.

In comparison to this, the G-factor of cookie dough was relatively high, showing a value of 0.69. That is, the perception of liquid and solid concept attributes appeared more clearly, as cookie dough was not seen as a solid or a liquid but a material that cannot be classified. Accordingly, the response type of the students changed from LM to HH. In particular, though the students thought cookie dough was a solid because it has a "fixed shape" and "fluidity," as the point that the difference in the mixed amounts causes such a characteristic was perceived in the discussion, the answer that it could not be classified was stabilized as the correct answer.

Student B: Isn't cookie dough a mixture of water and powder?
Student A: However, cookie dough maintains a fixed shape if it is left untouched.
Student C: By the way, won't it flow if a lot of water is added?
Student B: I know. Isn't water found in cookie dough along with a lot of flour, butter, and sugar?
Student D: Then, it contains solids and also liquids. It is difficult to express what it is in a word if many things are mixed.

The results of the classification activity of humans showed an RCA of 0.44, a C-factor of 0.36, and the response type of MM. The two mainstream responses were that humans are classified as a solid and that the state cannot be classified. In particular, differently from the examples presented earlier, the peculiarities of human beings were shown to have an effect on students' answer that humans are not classifiable. That is, through interviews, the students were found to think that human beings cannot be classified as matter because they are living things. Additionally, in the results of the preceding study[4], it was reported that some 3rd grade middle school students do not understand that the basic units living things consist of are matter.

Student G: Isn't a human being a solid? First, it can be touched and has a shape.
Student E: By the way, haven't we learned that 70% of our body consists of water?
Student F: It seems to be a solid as, though water is contained inside, the outside is in the form of a solid and does not flow down.
Student E: Mm, a human is a living thing. Can it be classified as a solid, liquid, or gas?

***Table* 9.** Item analysis by RCA, C-factor, G-factor, and pattern of response in mixture conception

Item	Concept	Pre-test		Pattern of level	Post-test		Pattern of level	G-factor
		RCA	C-factor		RCA	C-factor		
Pudding	Mixture	0.19	0.46	LM	0.42	0.36	MM	0.28
Cookie dough	Mixture	0.25	0.32	LM	0.72	0.60	HH	0.69
Human	Mixture	0.44	0.36	MM	0.96	0.92	HH	0.92

The RCA and C-factor in the classification result of humans after the discussion activity greatly increased to 0.96 and 0.92 respectively. In the above responses, as the points of view where a human is regarded as a mixture and where humans cannot be classified because they are living things are mixed, additional studies are needed to clarify the viewpoints of the students.

Among the three untypical example, pudding, cookie dough and human, it could be seen that the one that had the biggest effect on stabilization of the students' state classification concept attributes was cookie dough. If students stabilize the attributes of classification concepts through such learning activities, students will acquire the capability to effectively classify specific and diverse examples.

CONCLUSION AND IMPLICATIONS

Through this study, we reported that 3rd to 6th grade elementary school students have not yet grasped the attributes of state of matter classification concept presented in the current science curriculum. In particular, the percentages of the students who perceived "change in shape and volume" as the concept attribute of solid, "fluidity" as the concept attribute of liquid, and "perception of substance" and "prototype" as the concept attributes of gas were high.

As a result of confirming the firmness of students' perceptions by presenting examples that are different from the typical attributes of state of matter and as a result of inducing changes in concepts through a discussion activity, trends of returning to the concept attributes required in the current curriculum were not clearly visible with except in the case of 3rd grade elementary school students. In particular, this was the case with the 4th to 6th grade students even though they were cognitively more mature than 3rd grade students. Through this, it can be seen that the education method that has been traditionally continued needs to be changed. This is because the educational effect is thought to be difficult to achieve according to the current education method if not immediately after the state concept of matter is taught.

Though the curriculum has been continuously changed until the 2009 revised national curriculum, no big change has been made in the content and method of the education actually presented to students. Accordingly, the contents of state concepts of matter presented in the traditional way have existed for decades. Although education can be said to be a product of traditional thought, not many studies have analyzed and presented such a problem of education method in detail. The meaning of this study can be found in that the problem of learners' learning effect is presented under the subject of "The Characteristics of States of Matter Concept Attributes." Although many studies introduced alternative scientific conceptions of students and reported the educational effects by applying diverse teaching methods, such studies were carried out within a year during which the study course took place. Accordingly, as reported in this study, almost no attention was paid to the thought returning phenomenon of the students afterwards.

In this study, we have looked at the issue of which examples more effectively induce stabilization of students' perception of concept attributes through a classification activity of mixtures that are untypical example of state concept attributes of matter. Though this study has been conducted with exemplary cases, if such studies are conducted more systematically, it is thought to help in constructing the content of textbooks that can enhance the educational effect later. Particularly, it is thought to be quite necessary to make efforts to stabilize the students' state concept attributes of matter by including a learning process where students find and correct errors of attributes by themselves by grasping characteristics such as "perception of substance," "prototype," or "perception of position" generally accepted by students as attributes that classify states of matter and cause a cognitive conflict through related untypical example. We have shown the importance of such an attempt in this study by presenting the static correlation between the RCA and the G-factor after a discussion activity.

Based on the above study results, we intend to suggest the following: when revising textbooks from now on, a study on a teaching plan is required to be carried out that enables students to apply the state concept attributes of matter with consistency by themselves. In this study, the students applied different concept attributes in accordance with diverse examples. For example, while the state of water was classified using "fluidity," the state of steam was classified using the attribute "perception of substance." Accordingly, the students guided the explanation of each example and the classification result in different directions. Therefore, an educational experience needs to be provided to enable such problems of students to be grasped and to allow consistent attributes of classification concepts to be effectively grasped.

Additionally, science educators need to discuss whether examples of mixtures should be included in the classification of states of matter or not. As mixtures do not clearly show the state concept attributes of matter, if mixtures are presented as examples, a problem may be caused where the confusion of students rather than understanding becomes bigger. Of course, mixtures can be utilized as tools to make clear the state concept attributes of matter by presenting them as untypical example of state of matter classification. However, rather than such an educational attempt, there is a tendency of presenting mixtures as typical examples of state of matter classification in the current textbooks. Accordingly, students should not just be taught only that matter can be classified into one of the three states; it is required to reorganize educational contents to enable students to understand that state "cannot be classified" as in the case of mixtures. This will make school science closer to actual science and provide students with the chance to experience the nature of science. In relation to this, the example of Professor Dan Shechtman of Israel can be taken, who won the 2011 Nobel Prize in chemistry for discovering the quasi-crystal state. He went through many difficulties until he overturned the established theory of the existing textbook. He said that the most important attitude of scientists is to be "humble but not trust textbooks." When he proposed new classification concept attributes of matter, though it was an attempt to break the conservative paradigm of the existing classification concept of matter, the resistance of other scientists against this was fierce. In particular, Pauling, who won the Nobel Prize twice, disparaged Professor Shechtman, calling him "a quasi-scientist." If we effectively provide a way to understand the examples that are out of the typical state classification attributes of matter by presenting examples of mixtures to students, we can teach students, through this, creative thoughts that enable them to aggressively throw away the scientific concept they possess when this concept fails to explain a new phenomenon and generate a new science concept suitable for the new phenomenon.

Acknowledgments. Publication cost of this paper was supported by the Korean Chemical Society.

REFERENCES

1. Ministry of Educational and Science Technology. *Science Curriculum*; Ministry of Educational and Science Technology: Seoul, 2012.
2. Harrison, A.; Treagust, D. The Particulate Nature of Matter: Challenges in Understanding the Submicroscopic World. In *Chemical education: towards research-based practice;* Gilbert. J. K., de Jong. O., Treagust. D. F., van Driel. J. H., Eds.; Kluwer: Dordrecht, 2002; pp. 189-212.
3. Stavy, R. *School Science and Mathematics* **1991**, *91*(6), 241.
4. Park, I. S.; Kang, S. H. *Journal of Research in Curriculum Instruction* **2009**, *13*, 1.
5. Stavy. R.; Stachel. D. *European Journal of Science Education* **1985**, *7*, 407.
6. Lee, E. S.; Park, J. H. *Journal of Research in Curriculum Instruction* **2008**, *12*, 183.
7. Kang, T. J. A. Study on Elementary student's Conceptions on the State and the State Change of Matter. Master Thesis, Korea National University of Education, 2000.
8. Choi, K. S. A Survey in Middle School First Grade Students' Conception on the State and State Change of Matters. Master Thesis, Korea National University of Education, 2003.
9. Kim, H. J.; Nam, H. J. *Journal of Korean Elementary Science Education* **1997**, *16*, 135.
10. Kim, S. K.; Kim, Y. M.; Paik, S. H. *Journal of the Korean Chemical Society* **2008**, *52*, 569.
11. Kwon, J. S.; Kim, B. K.; Woo, J. W.; Jeong, W. H.; Jeong, J. W. *Science Education*; Kyoyookgwahaksa: Seoul, 2006.
12. Choi, J. I.; Paik, S. H. *Journal of the Korean Chemical Society* **2015**, *59*, 320.
13. Siegler, R. S.; Alibali, M. W. *Children's Thinking*, 4th ed.; Prentice Hall: Upper Saddle River, NJ, 2005.
14. Kim, Y. M. J. A Research in Conceptions of Phases of Matter. Master Thesis, Korea National University of Education, 2006.
15. Paik, S. H.; Choi, J. I.; Park, E. J. *Journal of the Korean Association for Research in Science Education* **2013**, *33*, 1273.
16. Lee, S. K. Conceptual Change in Learning Science; SNU Press: Seoul, 2015.
17. Hake, R. R. *American Journal of Physics* **1998**, *66*, 64.
18. Coletta, V. P.; Phillips, J. A. *American Journal of Physics* **2005**, *73*, 1172.
19. Kim, H. J.; Im, S. M. *New Physics: SaeMulli* **2011**, *61*, 26.
20. Lee, J. W.; Shin, E. J.; Kim, J. B. *Journal of Korean Elementary Science Education* **2015**, *34*, 357.
21. Mayer, K. *Journal of Chemical Education* **2011**, *88*, 111.
22. Bao, L.; Redish, E. F. *American Journal of Physics* **2001**, *65*, 45.
23. Kim, H. J.; Im, S. M. *New Physics: SaeMulli* **2011**, *61*, 26.
24. Krnel, D.; Watson, R.; Glažar, S. A. *International Journal of Science Education* **2005**, *27*, 367.
25. Babai, R.; Amsterdamer, A. *Journal of Science Education and Technology* **2008**, *17*, 553.
26. Janice, K. *Science Methods for Elementary and Middle School Teachers*, 4th ed.; Kim, Y. J.; Park, H. J.; Paik, S. H.; Son, J. W.; Oh, W. K.; Oh, P. S.; Yoon, H. K.; Lee, K. Y.; Lee, B. W.; Jeong, J. I.; Han, J. Y. Trans.; Books hill: Seoul, 2011 (original work published 2010).

***Appendix* 1.** The results of students' classification of matter states in various examples by grades

Grade	Response	Smoke		Wheat flour		Cotton		Soft fabric		mist	
		pre	post	pre	post	Pre	post	pre	post	pre	post
3 <30>	Solid	0	0	17(56.6)	21(70)	20(66.7)	17(56.6)	23(76.7)	25(83.3)	0	0
	Liquid	2(6.7)	0	2(6.7)	0	0	0	0	0	2(6.7)	0
	Gas	21(70)	25(83.3)	0	0	2(6.7)	4(13.3)	0	0	21(70)	25(83.3)
	Cannot classified	2(6.7)	5(16.7)	10(33.3)	9(30)	5(16.7)	9(30)	2(6.7)	5(16.7)	3(10)	5(16.7)
	Nonresponse	5(16.7)	0	1(3.3)	0	3(10)	0	5(16.7)	0	4(13.3)	0
4 <25>	Solid	0	0	14(56)	25(100)	14(56)	20(80)	20(80)	20(80)	0(0)	0
	Liquid	1(4)	0	0	0	1(4)	0	0	0	2(8)	0
	Gas	23(92)	9(36)	3(12)	0	3(12)	0	0	0	20(80)	14(56)
	Cannot classified	0	16(64)	6(24)	0	3(12)	5(20)	3(12)	5(20)	1(4)	11(44)
	Nonresponse	1(4)	0	2(8)	0	4(16)	0	2(8)	0	2(8)	0
5 <27>	Solid	0	0	15(55.6)	27(100)	17(63)	23(85.2)	20(74)	23(85.2)	0(0)	0
	Liquid	0	0	2(7.4)	0	0	0	1(3.7)	0	2(7.4)	4(14.8)
	Gas	24(88.9)	23(85.2)	0	0	1(3.7)	0	0	0	22(82.5)	23(85.2)
	Cannot classified	2(7.4)	4(14.8)	8(29.6)	0	4(14.8)	4(14.8)	3(11.1)	4(14.8)	2(7.4)	0
	Nonresponse	1(3.7)	0	2(7.4)	0	5(18.5)	0	3(11.1)	0	1(3.7)	0
6 <31>	Solid	0	0	22(71)	22(71)	22(71)	27(87)	26(83.9)	27(87)	0(0)	0
	Liquid	0	0	3(9.7)	0	2(6.5)	0	1(3.2)	0	1(3.3)	0
	Gas	31(100)	17(54.8)	1(3.2)	0	3(9.7)	0	2(6.5)	0	30(96.7)	27(87)
	Cannot classified	0	14(45.2)	4(12.9)	9(29)	1(3.2)	4(12.9)	1(3.2)	4(12.9)	0(0)	0
	Nonresponse	0	0	1(3.2)	0	3(9.7)	0	1(3.2)	0	0(0)	4(12.9)
Grade	Response	Cloud		Steam		Pudding		Cookie dough		Human	
		pre	post	pre	post	pre	post	pre	post	pre	post
3 <30>	Solid	0	0	0	0	19(63.3)	8(26.7)	18(60)	0	18(60)	0
	Liquid	1(3.3)	0	4(13.3)	0	3(10)	0	2(6.7)	0	0	0
	Gas	19(63.3)	17(56.7)	20(66.7)	25(83.3)	1(3.3)	0	0	0	0	0
	Cannot classified	4(13.3)	13(43.3)	2(6.7)	5(16.7)	4(13.3)	22(73.3)	5(16.7)	30(100)	10(33.3)	30(100)
	Nonresponse	6(20)	0	4(13.3)	0	3(10)	0	5(16.7)	0	2(6.7)	0
4 <25>	Solid	1(4)	0	1(4)	0	15(60)	5(20)	13(52)	16(64)	10(40)	0
	Liquid	3(12)	4(16)	2(8)	4(16)	5(20)	15(60)	5(20)	0	0	0
	Gas	16(64)	12(48)	18(72)	14(56)	0	0	1(4)	0	1(4)	0
	Cannot classified	2(8)	9(36)	1(4)	7(28)	4(16)	5(20)	4(16)	9(36)	14(56)	25(100)
	Nonresponse	3(12)	0	3(12)	0	1(4)	0	2(8)	0	0	0
5 <27>	Solid	0	0	0	0	15(55.6)	19(70.3)	11(40.7)	4(14.8)	13(48.1)	0
	Liquid	1(3.7)	11(40.7)	2(7.4)	12(44.4)	1(3.7)	0	1(3.7)	0	1(3.7)	0
	Gas	20(74)	8(29.6)	19(70.4)	11(40.7)	1(3.7)	0	1(3.7)	0	0	0
	Cannot classified	3(11.1)	8(29.6)	4(14.8)	0	9(33.3)	8(29.6)	11(40.7)	23(85.2)	11(40.7)	27(100)
	Nonresponse	3(11.1)	0	2(7.4)	4(14.8)	2(7.4)	0	3(11.1)	0	2(7.4)	0
6 <31>	Solid	0	0	1(3.3)	0	27(87.1)	17(54.8)	29(61.3)	0	15(48.4)	5(16.1)
	Liquid	3(9.7)	0	4(12.9)	4(12.9)	1(3.2)	0	5(16.1)	4(12.9)	0	0
	Gas	26(83.9)	18(58)	22(71)	22(71)	0(0)	0	0(0)	0	2(6.5)	0
	Cannot classified	1(3.3)	13(41.9)	0	5(16.1)	3(9.7)	14(45.2)	6(19.4)	23(74.2)	13(42)	26(83.9)
	Nonresponse	1(3.3)	0	4(12.9)	0	0	0	1(3.2)	4(12.9)	1(3.2)	0