How do Elementary Students Classify the Branches of Science?

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Abstract: Science curriculums for elementary schools were, traditionally, developed to be balanced in content and contain equal proportions of the four branches of science: physics, chemistry, biology, and earth science. To develop a successful science curriculum, we asked some questions about how elementary students recognize these branches and about what they think of the domains of science in the science curriculum. Our study was designed to investigate how elementary students classify the domains of science in the curriculum.

Previous research (Lee *et al*., 2001) seemed not to be successful, because verbal expressions in that research might be inappropriate for elementary students who were unaccustomed to the technical language of science. For this reason, instead of using only words, we developed image card instruments, made of picture duplicates of the introductory covers of each unit in the 3rd, 4th, and 5th grades' science textbooks.

We asked students to classify these cards into their own categories and record the reasons for classifying them. The ratio and distribution of the units was then analyzed to identify their view of the science domains.

30% of the 4th grade students created the following categories: 'nature,' 'observation,' 'seasons,' 'living things,' 'sounds,' 'separating,' and 'the things necessary for everyday life'. In the case of the 5th grade, over 30% created the categories of 'living things,' 'weight,' and 'water.' Over 30% of the 6th grade created the categories of 'nature,' 'light,' 'water,' 'living things,' 'solution,' 'fire,' 'properties of an object,' and 'experiment.'

Upon scrutinizing the above results, we discovered that the science domains selected by students into three types of domains: academic contents and concepts; activities related to a science class; and lessons and experiences in students ' lives. The last category was a new, complex kind of domain.

We concluded that students did not utilize the four branches of science when constructing their own domains of science. Instead, they created many alternative domains, which reflected students' thoughts of and their experiences. The educational needs of elementary students suggest that when organizing science curriculum as 25 % allocation of the four science branches, newly-created domains should be considered.

Key words: organization, science curriculum, science domains, image cards

I. Introduction

The science curriculum has always been an important starting point, providing the aim and the contents of science education. It reflects the efforts we made to create a 'real' value in education, answer the demands of higher education, and address the needs of our economic system and the nation as a whole. These efforts were based upon the educational paradigm that reflected the social change and current thinking of each time period. They also took into consideration how to make science more attractive to more students (DeBoer, 1991).

Thus far, Korean science curriculum was revised since seven times. In the late 1950s, the science curriculum changed to incorporate the new ideas of the educational revolution that had started in America. Then in the 1960s, progressives, trying to be innovative, created a new curriculum based on the aims and contents of a life-centered curriculum. The 3rd revision was based upon a discipline-based philosophy (Ministry of Education, 1995). Conversely, the 4th and 5th curriculum revisions criticized the disciplined-based philosophy. As shown above, accepting new educational paradigms, changing the contents of curriculums, and the new teaching

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methods for these new paradigms caused several significant revisions of the Korean science curriculum. (Song *et al.*, 2003).

Science subjects took specific positions and each had its own sequence based upon its original philosophy and contents. In the 7th Korean science curriculum, the knowledge content is classified into 4 branches such as energy, material, life, and earth which correspond to physics, chemistry, biology, and earth science. Thus the current structure of the 7th science curriculum has four branches sequence. Historically, the basic organization of the 7th science curriculum was affected by Bruner's theory (1977), which was influential in the innovations in science curriculum. When the logical structure of discipline and the process of science were emphasized, this resulted in the discipline-based curriculum. Until now, we have developed our curriculums under the influence of this theory (Jeong *et al.*, 1996). However, Bruner's theory of sequence of curriculum achieved results by ignoring the problems; that is, when we structure the curriculum, we have to present the knowledge of science by connecting with students' experience and, at the same time, make it interesting for them.

When the four branches in science were set up in a curriculum, the sequence of the branches resulted in a structure that kept an equal proportion of time in every grade's curriculum. The lesson time for teaching each branch of science had to be evenly distributed as much as possible by balancing the contents in an elementary school. Unfortunately, this form is only concerned with the branches of science without considering the learner. The discipline-based curriculum, which was developed by a logical sequence of knowledge, could not ensure students' logical sequence (McKeen & Eisenberg, 1973). The structure of knowledge captured by the learners exists in different ways (Cho, 1988). The curriculum based on the experts' logical structure did not always acquire the maximum level of learning. Hence, we need to consider the cognitive structure of the learners when we construct a curriculum (Bodner, 1986).

Hierarchy of curriculum had been considered as the principles of vertical structure and students' principles of structuring knowledge by their experiences. However, this approach had always carried out only within each branches of science. For example, the research on the hierarchy in physics was solely concerned with the contents of physics and did not consider chemistry or any other field. That is to say, the sequence of the branches of science (chemistry, physics, earth science and biology) could not help being exposed to the limitations set by the point of view that the curriculums need to be structured vertically as well as horizontally with the view of students. Therefore, it is imperative that we consider children's characteristics of structuring their science domain.

Meanwhile, the principles of integrative science curriculums were focused on concept, process and phenomena. It also did not follow the system as 4 branches. In addition, the latest principles of integration of science branches related STS gained force with the assertion that the social problem had to became the central point of all science education. However, there are some limits in those efforts. The reality of the development of an integrative science curriculum, which relied on a horizontal structure of curriculums, was not very successful. This was due, in part, to the way how to integrate each branches of science. Recently, there have been some movements for developing the new curriculums based on the nature of science. This curriculum took a good look at the characteristics of the science branches by using our recognition and thinking capabilities when related with the nature of science. Yet, they had some limitations since the curriculums were being controlled by the sequence of branches (Choi, M. H. & Choi, B. S., 1999).

It is ironic that despite the philosophical foundation of the 7th science curriculum interrelating with constructivism, the structure of the curriculum is still too focused on the 4

branches of science. Constructivism requires teachers should figure out students' conceptions: the understanding of scientific concepts for effective learning to occur. Moreover, teacher should also consider the way students structure concepts (Kang, 2001). The system and the organization of scientific concepts to learn, that is subjects about vertical and horizontal organization of scientific concepts in the curriculum, need to reflect the characteristics of the children's domain of science. However, regardless of how much research has been done to identify students' misconceptions or the way students can learn scientific concepts more effectively, the constructivist researchers of science education were very hesitant to research a new system of science curriculum based on students (Lim and Kim, 1998). Therefore, the most integrative science curriculums developed were based on the structure of knowledge but were far from students' perspectives.

Even though the schemes of the curriculum were well-organized within the branch of science, students' representations might differ from those schemes. It is very important to discover how students recognize the branches of science in order to organize an effective science curriculum to be consistent with constructivism. We must begin this work by probing students' domains of science in elementary school science curriculums.

Ⅱ. Purposes and Process

The main purpose of this study is to figure out elementary students' domains of science within the contents of the national science textbook of the 7th Korean science curriculum. Researches into how did students classify the science domain with their own standards is essential for developing effective science curriculum. If we know how students classify the science contents with their thinking or experience, it will guide teachers to structure the main frame of the curriculum. It is especially important to elementary students with systematic experience of science branches, because domains represented by elementary students could be very different from the traditional academic branches (Lee *et al.*, 2001).

First, by reviewing previous research, the concept of scientific branches was validated and analyzed branches' distribution in the science textbooks units of the 7th Korean curriculum. By this process, the characteristics of distribution of each branch of science were clarified. Then, in order to investigate how elementary school students classified the science domains, image cards representing units of each branch of science from the 3rd to 5th grades were developed and were shown to a total of 269 public elementary students (96 from the 4th grade, 94 from the 5th grade, and 79 from the 6th grade). The image cards were reproduced by the cover of the units of the previous year's science textbooks. Students were asked to classify image cards and to write the reasons for their classifications. Then, the reasons and the distribution ratio of the units and branches in each category were used to find the characteristics of students' science domains.

Ⅲ. Methods

Previous research has been done to find science domains of the 6th grade students of elementary school (Lee *et al.*, 2001) using terms in science textbooks. The meaning of a concept used in a science class would be represented by terms. Terms are the base of understanding, thus, these are very important in learning. The result of research such as: a student who was familiar with the scientific terms used had more ability to understand concepts than students who are not, also proved the above (Gardner, 1974). Usually, the meanings of terms were gained by direct experience. Some students had already met certain scientific concepts prior to being introduced to them on the classroom. In such instances, understanding the scientific term can be easier. However, when direct experience had not occurred, indirect experience such as a picture or image would be used in the science classes to

aid students' understanding. On the other hand, sometimes understanding the important target terms artificially given in the science class was not an easy task for students. Students were influenced by many factors when they encountered scientific concepts, so sometimes could not understand the correct meaning of terms. The mother tongue or native language can be an influencing factor of understanding terms (Marshall & Gilmour, 1990). Contrary to the term, the visual instrument could come close to the student as an easy and familiar task. Hence, this study used visual supplementation to correct that weak point of previous research

The Merits of Image Cards

The image cards would be interpreted by the student as a visual language. As the visual language has meaning and concept, it can interact with the interpreter as well as a colloquial language (Lee, 2000). Image cards as a visual language had some merits.

First, the visual language had the 'focus effect,' arousing the attraction and interest of students compared with simply presenting the term. Students concentrated their attention better, and it became a synthetic media connected directly with vision and sense (Kim, I. G. & Kim, Y. S., 1996).

Second, the visual language was more accurate than other languages when we selected the meanings of some objects. The image incorporated many characteristics of an object. In the other hand, the one term of an object cannot express those characteristics together. Image can show many messages at once. In connection with this merit, the research using the image cards to express the contents of each unit will make the student grasp the contents of unit more accurately (Arnheim, 1995).

Third, recognition is the mental process that makes experience change to encode memory (Baddeley, 1980). If we use the term 'spring' and show 'image cards connected with a spring' to students who participated in activities using a spring the prior year, the term 'spring' will make students think of the concept and meaning of 'spring' and recall the memory related with this learning. However, the 'photograph of spring' that students used in the science class before, will also make the student think of those things, but the memory in this process will be more accurate. In addition, by using photographs from the class, their memory improves when compared to using only a term. The image is the more effective instrument to make students recall their learning.

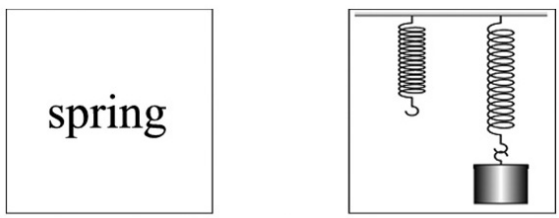

Fig. 1 *Image*

Fourth, the reason for using the image cards in this research related the scientific term used over the units. If we gave the term 'flower' to students, and asked them remember the scientific activities or contents, this term would not represent the unit we proposed effectively because the 'flower' was, in some units, used as a main subject, and in others, as a or material for performing experiments. For example, in the 5th grade science textbook, there are units on making an indicator from a flower petal and on observing flowers. In this case, the method using term is not appropriate to the aim in this research. We hope the student will recall the totality of the scientific concept or activities learned in science classes by each unit. As the term 'flower' was used in many units from many branches, students remembered a number of activities and scientific experiences from multiple units. As a result, the term was integrated into many branches. However, utilizing a picture from a specific unit, the entirety of the memory incorporated by that unit can be captured. Supplementing terms with visual material overcomes the weakness noted above,

and is more adaptable when inspecting the characteristics of students' science domains. For this reason, instead of using only words, we devised classification tasks for identifying domains of science using image cards.

Classification Task of Image Cards

We made classification tasks of total 48 image cards using the pictures from all of covers of each unit in the 3rd, 4th, and 5th grades' science textbooks (examples in Figure 2). Initially, we removed any hints about names and letters in cards. If students could not comprehend an image, we replaced the letters after advices from experts. Also, if the picture was too abstract to express the process of learning in the unit, we replaced it with another picture from the unit, after experts' consideration.

Elementary students were asked to classify image cards from science units that had been learned in school the previous year. Students in the 4th grade classified 16 cards from the 3rd grade science textbook, the 5th grades did 16 cards for the 4th, and the 6th grades did 17 cards for the 5th grade textbook. The elementary students recorded the reasoning behind the classification of each image card.

It is difficult to control them to make standards only by the scientific concept they learned before. Thus when we give the picture cards to students, we mentioned from where those pictures were taken. However, some of students focused on the

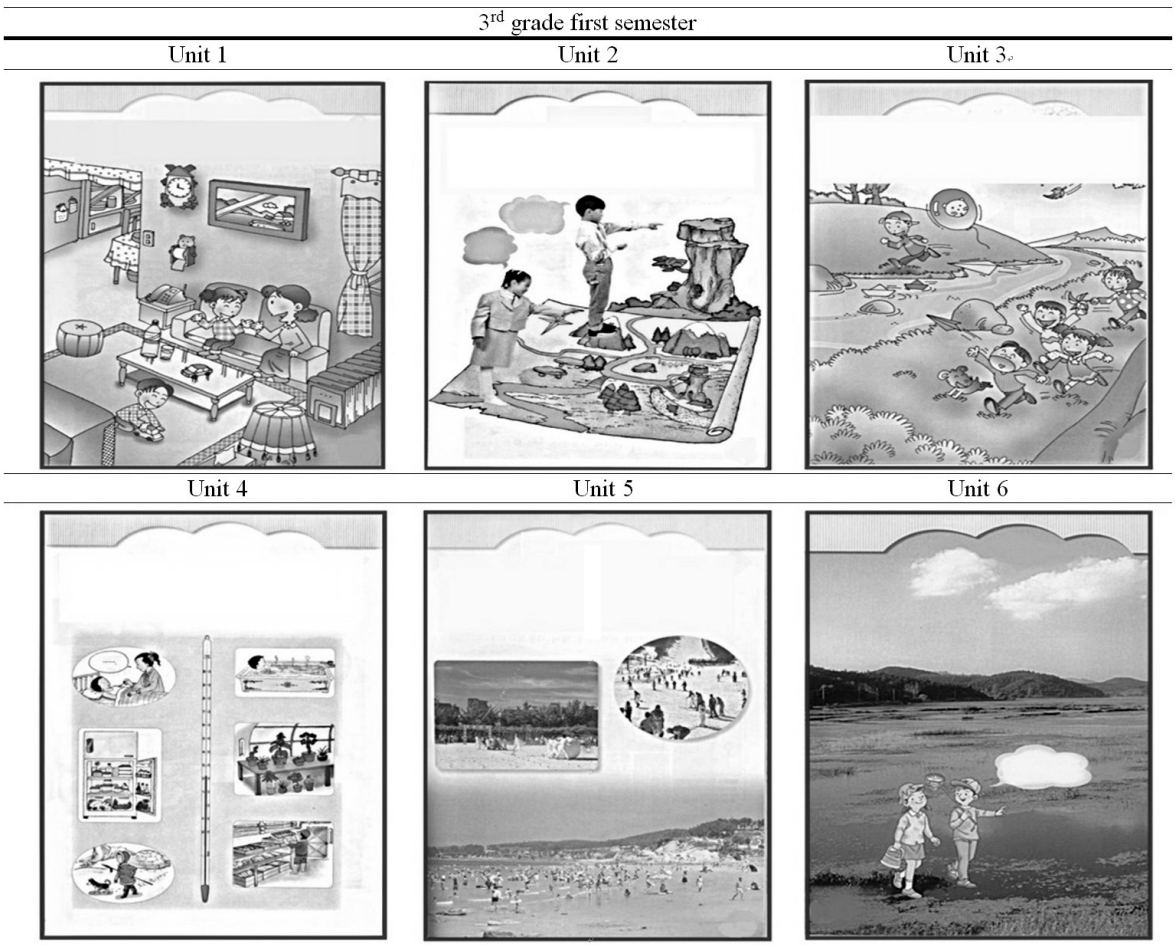

Fig. 2 *Examples of image cards by the units*

picture itself. So we assumed that students could benefit scientific concepts and memory because they had learned units with pictures in a last year. Applying this method in the research leads to limit to understand real meaning of categories made by students, but it's possible to identify students' domains of science.

The answers of 9 students were removed from the analysis because, their inspirations did not relate with any scientific contents. Thus, we thought they did not engage in the classifying process. Also, some listed two or three standards for one category when they classified the image cards, so their answers were seen as anomalies.

Ⅳ. Results of analysis of units in each science branch

The distribution of branches of science units in the 7th Korean science curriculum are shown in tables 1 to 4. Each branch had almost equal proportions of 25%. Moreover, there were few differences between each grade. But the 'life' branch took 3 units out of 15 total units, so the frequency was 20.6% in the 3rd grade. Lower frequency of the 3rd grade was amended in the 5th grade level, that taking 5 units of 'life' branch out of 17 total units, so the frequency was 29%. In the 6th grade, units of the 'earth' branch had a high frequency of 30.7%. After analyzing the distribution of branches in every grade, the each frequency of 'energy', 'material' and 'life' was 24.5%. 26.2% of science curriculum composed of the branch 'earth'. Even this small difference, Korean science curriculums had been typical and quarter proportions of each branches of science.

Table 1
The distribution of science branches in the national science textbook (3rd)

The 3rd grade 1st semester		The 3rd grade 2nd semester	
Unit title	Branch	Unit title e	Branch
1. The matter of the surrounding	Chemistry	1. The leaf and the stem of plants	Biology
2. Magnetic playing	Physics	2. The advance of the light	Physics
3. The valuable air	Chemistry	3. The earth and the moon	Earth science
4. Measuring temperature	Physics	4. Dissolving the various powders	Chemistry
5. The weather and our life	Earth science	5. The various stones and the soil	Earth science
6. The living things under the water	Biology	6. Making sound	Physics
7. The life cycle of a drosophila	Biology	7. Separating the blending granule	Chemistry
8. The water carrying the Earth	Earth science		

Table 2
The distribution of science branches in the national science textbook (4th)

The 4th grade 1st semester		The 4th grade 2nd semester	
Unit title	Branch	Unit title	Branch
1. Keeping the Horizontality	Physics	1. Appearance of Animal	Biology
2. The liquid and our life	Chemistry	2. The Gender of Animals	Biology
3. Light a bulb	Physics	3. For finding the strata	Earth science
4. The kidney bean	Biology	4. For finding the fossil	Earth science
5. Separating the mixture	Chemistry	5. Change the volume of object by heat	Chemistry
6. The root	Biology	6. Hanging down the spring	Physics
7. The River and the sea	Earth science	7. The water changing appearance	Chemistry
8. For finding the constellation	Earth science	8. Moving of the heat and our life	Physics

Table 3
The distribution of science branches in the national science textbook (5th)

The 5th grade 1st semester		The 5th grade 2nd semester	
Unit title	Branch	Unit title	Branch
1. The mirror and the lens	Physics	1. The environment and living things	Biology
2. Dissolution and solution	Chemistry	2. The properties of solution	Chemistry
3. The temperature and the wind	Earth science	3. The fruit	Biology
4. The speed of object	Physics	4. The volcano and the rock	Earth science
5. The flower	Biology	5. The reaction of solution	Chemistry
6. The thick level of solution	Chemistry	6. Making the electric circuit	Physics
7. The work of leaf	Biology	7. The family of the sun	Earth science
8. The travel of water	Earth science	8. The energy	Physics
9. The small living things	Biology		

Table 4
The distribution of science branches in the national science textbook (6th)

The 6th grade 1st semester		The 6th grade 2nd semester	
Unit title	Branch	Unit title	Branch
1. The properties of gas	Chemistry	1. The weight and the pressure of under the water	Physics
2. The earthquake	Earth science	2. The weather forecast	Earth science
3. The appearance of our body	Biology	3. The comfortable environment	Biology
4. The various rocks	Earth science	4. The change of season	Earth science
5. The living things of surrounding	Biology	5. The combustion and the extinguishing	Chemistry
6. The various gases	Chemistry	6. The convenient instrument	Physics
7. The electromagnet	Physics		
No. of the branches from the 3rd to 6th (%)			
Physics:15 (24.6%) Chemistry:15 (24.6%) Biology:15 (24.6%) Earth science:16 (26.2%)			

Ⅴ. Students' Domain of Science

Frequency of Categories

Elementary students classified image cards from two to ten categories shown in table 5. Most of them made 4 or 5 categories. However, most of the 4th grade students made 3 to 5 categories. Categories made by students with similar meanings were combined into representative categories. As a result, the 6th grade had 30 categories, the 5th grade had 37 categories and the 4th grade had 30 categories.

Table 6 shows the categories made by over 10% of the each grade level students. Most students classified image cards by concentrating on the subject treated in the science classes. The selection of categories by students was influenced by their experiences, memories and views relating everyday life.

The distribution of categories in each grade

Figure 3 shows distribution of categories in each grade. The categories had made by over 30% of students were presented by each grade. For example, the 6th grade had 8 categories, the 5th, 3 categories, and the 4th grade, 6 categories.

Those categories offered by over 30% of the 6th grade students were 'living things', 'light', 'water', 'solution', 'nature', 'fire', 'properties of an object', and 'experiment'. The categories 'nature', 'water' and 'fire' gave the possibility of integrating scientific domains. Over 30% of the 5th

Table 5
The numbers of category classified by elementary students

Grade	No. of categories									
	1	2	3	4	5	6	7	8	9	10
4th	1.0%	2.1%	22.3%	29.7%	29.7%	13.8%	2.1%	0	0	0
5th	0	15.3%	8.9%	26.7%	23.7%	16.8%	5.1%	2.9%	1.0%	1.0%
6th	0	3.7%	8.8%	27.8%	32.9%	16.4%	7.5%	2.5%	0	0
Total	0.3%	7.0%	13.3%	28.0%	28.7%	15.6%	4.9%	1.8%	0.3%	0.3%

Table 6
Categories made by elementary students

Grade	Categories		
	Over 10% of students	Over 30% of students	Over 50% of students
4th	Appearance of surrounding, Water, Direction, Mountain, Light, The rock, Outside activity	Nature, Sound, Separation, Observation	Living things, Season, The things that students think are necessary for everyday life
5th	Nature, The Earth, The things that students think, The things that students think are necessary for everyday life, Light, Flower The things that need much time	Weight	Water, Living things
6th	Environment, Natural disasters, Wind, Things that move, Temperature variations, Our life, Energy, Earth, Speed, Cultural assets	Nature, Fire, Properties of an object, Experiment	Living things, Light, Water, Solution

grade students presented three categories: 'living things', 'water' and 'weight'. The reason for this was the contents of the 4th grade science curriculum. As a result of classification by the 4th grade students, the categories presented by over 30% of students were: 'The things that students think are necessary for everyday life', 'living things', 'season', 'nature', 'sound', 'separation' and 'observation'. Compared to the 5th and 6th grade students, the 4th grade students selected categories relating more to their daily lives. The biggest category, 'living things' was presented at every grade level, especially in the case of 5th graders, where 88.7% of students made this category. These categories had a tendency to be more closely integrated with scientific domains.

Many of the 6th and 4th graders presented the 'nature' category. However, only 17.5% of the 5th grade students presented 'nature'. The reasons were the themes of each unit and students' thinking about 'nature'. Even 'nature' was a broad concept; most of the units of the 3rd grade textbook did not comprise appropriate subjects to match 'nature'. Rather, most of the 4th grade students tended to classify these units as 'living things'. Only 24.4% of the 4th grade students presented 'nature', so this category was omitted in figure 3. Many other categories such as 'living things', 'the things that students think are necessary for everyday life' and 'fire' were present in every grade level but in some grades, the frequency was very low. The category 'water' that appeared at the 5th and 6th grade levels was a newly structured theme, inspired by students'

thinking, experiences and their own memories. The categories 'living things' and 'weight' represented their thinking about those themes.

The science domains (categories) by elementary students

Table 7 shows the categories obtained by over 30% of all students. When we merged the categories in each grade, the categories were counted together because the reasons given for creating the categories were similar. However, in some cases, despite categories' names being similar, the categories were not merged because reasons for their creation were very different.

The most-selected categories by over 30% of all students were 'living things', 'water', 'The things that students think are necessary for everyday life', 'nature', and 'light'. In these categories, 'living things' was selected by 80.2% of all students. This category contained small size categories such as 'plants', 'animals', 'life', etc. The category of 'water' was presented by 47.2% of all students. 'The things necessary for everyday life' was mostly offered by the 4th grade. In addition, 40.5% of all students produced this category. 'Nature' was presented by 35.5% of all students and 'light' was presented by 30% of students.

Each grade students made categories using one academic concept as a basis. However, each category was related with subjects or activities from over two units of two or three branches. This meant the student did not consider the branches of science when they made the categories. When they classified image cards, scientific concepts and their own way of thinking influenced their choices. This can be explained better by the categories produced by each grade.

Ⅵ. Patterns of making science domains

Analysis into characteristics of each category showed that students' thinking styles correlated to the classification of their categories which were their own domains. As students wrote down their reasons for making each category, we were able to take the information about what kind of domains

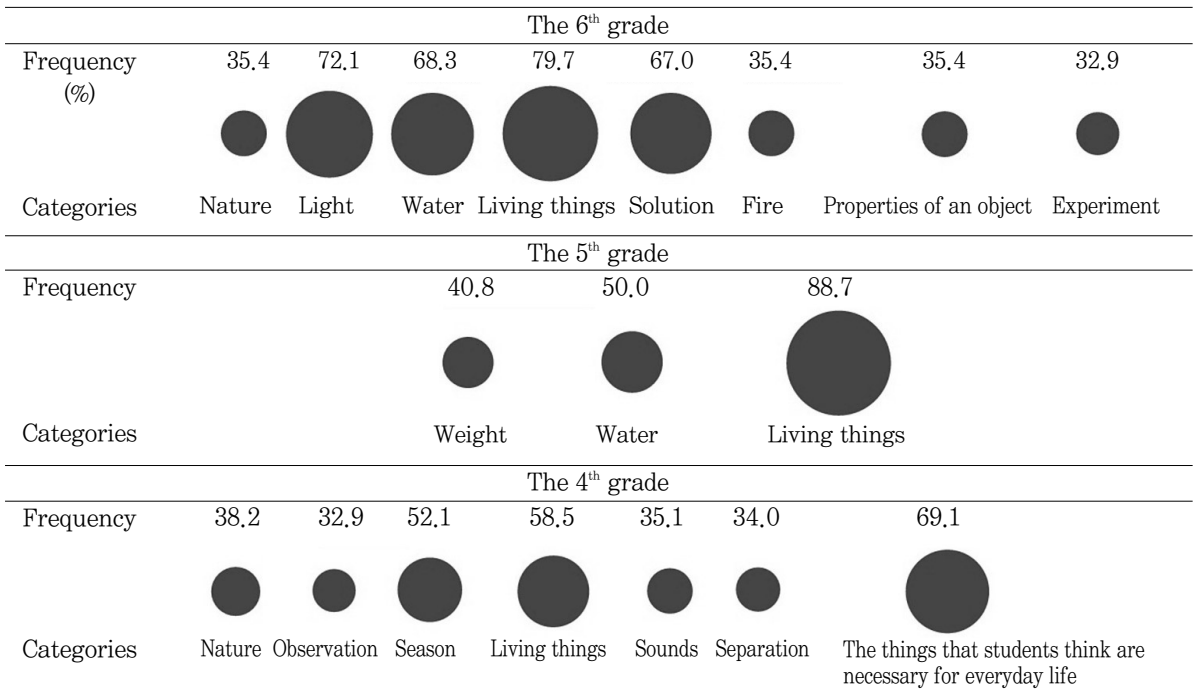

Fig. 3 *The distribution of the categories in each grade*

Table 7
Categories by all grades

Order	Domains	Small categories(No.)
1	Living things	The 6th grade: Living things, Plants, Animals, The living things underthe water(63) The 5th grade: Living things, Plants, Animals, Life(87) The 4th grade: Living things, Life,Plants(55)
2	Water	The 6th grade: Water, Feature if water,Floating(54) The 5th grade: Water(50) The 4th grade: Water, Fluid(23)
3	The things that students think are necessary for everyday life	The 6th grade: The things necessary foreveryday life, Instruments, Usedpoint(44) The 5th grade: The things necessary foreveryday life, The things can help, Instruments(23) The 4th grade: Using for everyday life(65)
4	Nature	The 6th grade: Nature, Principle of nature(32) The 5th grade: Nature(27) The 4th grade: Nature(36)
5	Light	The 6th grade: Light, Lens, Lightness, Mirror, Sight, Color, Being looked differently(57) The 5th grade: Light, Transparency,Lightness and darkness(11) The 4th grade: Light, Seeing,Color(15)

and what kind of units were more included in each category by analysis of the categories in each grade.

The collections of image cards gave us an insight into students' way of thinking as recorded. Each category tended to include certain units or branches more. Those became the characteristics of each category. The categories created by students became students' own science domains. After investigation of all of the categories, students' science domains were characterized by three ways: concepts of science, of activity, and of experience.

Classifying by concepts introduced in science class

Students made categories 'living things', 'solution', 'properties of an object', 'weight' and 'sound' by the foundation of academic contents and concepts.

Category 'Living things' (6th)

The 6th grade students made the category 'living things', which mainly composed of the units from the branch 'life'. Also this category of the 6th grade is different from the other grades' category 'living things'. The other grade units were so different that they could not be combined, for example, 'the properties of solution', 'the volcano and the rock', and 'making the electricity circuit' in the 5th grade. In the other grades, the 'living things' category included two branches of science; 'earth' and 'life'. In the 5th grade, the branch 'earth' took 12.3% of the category 'living things'. In the 4th grade, the branch 'earth' received the highest frequency of 26.6%. The reason was that the units of 'earth' were related with subjects such as the space or environment of living things. The unit of 'material' branch, 'valuable air' took only 9.7% of the 'living things' showed this reason in students' mind that air was indispensable to living things. That is to say, it seemed that students created category by concepts connected with their environment, knowledge and life experience.

Category 'Solution' (6th)

The 6th grade students created the category 'solution'. If the units incorporated any activity dissolving some materials, students placed the units in this category. The image cards of units from the 'material' branch, such as 'the thick

Order	Domain	Frequency of science branches				%
1	Living things	5.4% Energy	6.9% Material	72.3% Life	15.1% Earth	80.2
2	Water	15.9% Energy	45.0% Material	10.5% Life	28.4% Earth	47.2
3	The things that students think are necessary for everyday life	59.0% Energy	17.3% Material	10.5% Life	13.0% Earth	40.5
4	Nature	6.8% Energy	15.8% Material	35.5% Life	41.7% Earth	35.3
5	Light	65.6% *Energy	8.5% Material	1.5% Life	24.2% Earth	30.8

Fig. 4 *Top-5 Frequent Categories and four branches*
(*Energy, Material, Life and Earth are corresponding terms for Physics, Chemistry, Biology, and Earth, respectively)

level of solution', 'the reaction of solution', and 'dissolution and solution', made up the majority of the 'solution' category. Various activities of the solution resided in all of those units. 67% of all students made category 'solution'.

Category 'Properties of an object' (6th)

The 6th grade students created the category 'properties of an object'. They included many units having interesting experiments dealing with many different chemical materials. Generally, the category 'properties of an object' was composed of units of 'material' branch. These units of the 5th grade were 'dissolution and solution', 'the thick level of solution', 'the properties of solution' and 'the reaction of solution'. Students put the image cards of these units in this category. A total of 67% of the 6th grade students showed category 'solution'. 35.4% of the same students made the category 'properties of an object'. It means the category 'properties of an object' took a certain position among students' domains.

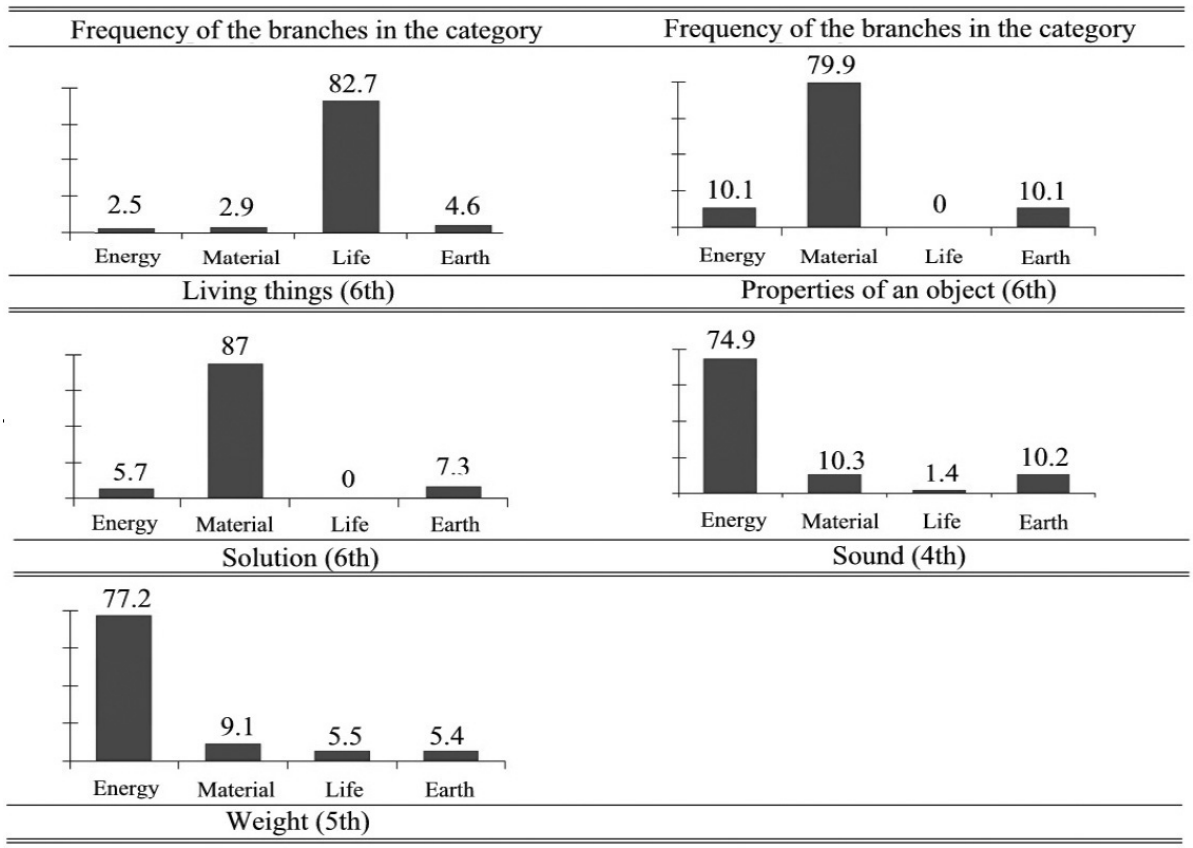

Fig. 6 *Categories by scientific concepts*

Category 'Weight' (5th)

The 5th grade students made the category 'weight'. They included units having activities related to gravity. Category 'weight' is heavily composed of units from the 'energy' branch (77.2%). In this category, each unit of the energy branch; 'keeping the horizontality' and 'hanging down the spring', took 36.5% and 33.9%. The 'weight' was difficult to connect with units from different branches.

Category 'Sound' (4th)

The category 'sound' was presented by 35.1% of the 4th grade students. They commented on their reasons here; 'sound', 'noise', and 'loudness' etc. The one unit 'making sound' occupied 74.9% of this category. There for, the category 'sound' is a particular theme that is difficult to integrate into other activities or subjects from different branches.

Classifying by centering on activities of science classes

Students made categories 'experiment', 'separation', 'observation' by focusing on activities related to science classrooms.

Category 'Experiment' (6th)

The category 'experiment' incorporated small categories such as 'experiment of everyday life', 'marvelous', 'research', 'observation', 'finding of the marvelous something', and 'principal of science'. These small categories were expressions representing the appearance of scientific activities. 32.9% of the 6th grade students presented this category. Strangely, branch 'material' took the highest frequency in this category. This was a result of students

recognizing their previous experiments. For them, the experiment activities were not ordinary experiences. They associated 'experiment' with various meanings, such as 'marvelous' and 'scientific'. Scientific activities and the experiment in branch 'material' were more adaptable for this association than any other field.

Category 'separation' (4th)

The 4th grade students presented the category of 'separation'. They commented that the units included here are related to the act of separation. 64% of this category composed of branch 'material'. The unit 'separating the blending granule' took 55.4% of this frequency. Curiously, the unit 'magnetic playing' occupied 16.7% of this category. This was caused by the learning activities revolving around iron powder from sand. Students focused on the separation process itself.

Category 'observation' (4th)

A total of 32.9% of the 4th grade students presented various activities relating to science, such as 'observation', 'investigation', etc. However, these were merged with 'observation'. They said the images related to 'observation'. In this category, the branches 'energy', 'material' and 'life' were distributed with similar frequencies. On the other hand, the 'earth' branch showed lower frequencies such as only 6%. The reason for this was the feature of the unit from the branch 'earth'. The units of branch 'earth' were 'the water carrying the earth', 'the earth and the moon' and 'the various stones and the soil'. All of these units composed of subjects that students could easily relate with. These units' activities focused on observing some outside appearance. For the student these were far from the interesting and attracting experiments carried out in the experiment room. Namely, their own recognition about scientific activities had affected this result.

Classifying by their own memory of experience and thinking

The categories created through students experiences and thinking were 'living things',

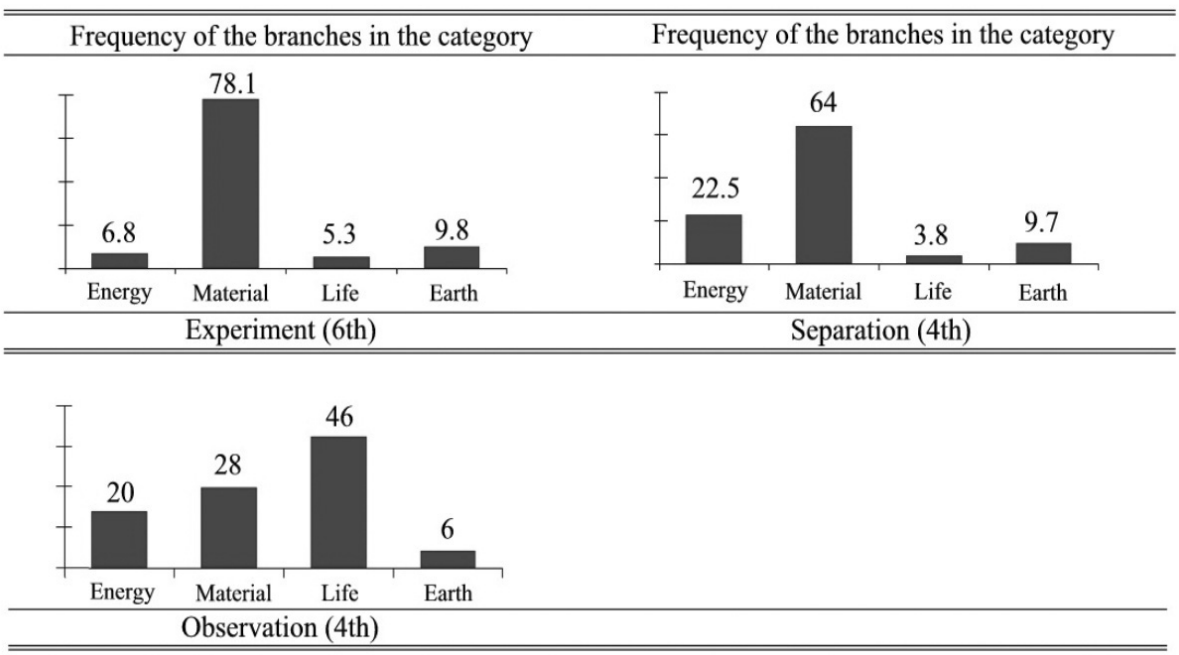

Fig. 7 *Categories by science activities*

'water', 'nature', 'fire', 'light', and 'for everyday life'.

Category 'Living things' (4th, 5th)

The category 'living things' was made by not only considering the concept of living things but also considering the environment of the life lives. In this point of view, the category 'living things' was located here. Students connected life with the living environment. Interestingly, the frequency of the branch 'earth' differed greatly from grade to grade. This was the result of the differences in the contents in the units of each grade. Some earth units could be related to the 'living things', but the others could not. This suggests that the new domain of science could incorporate some subjects of 'life' and some of 'earth'.

Category 'Water' (6th)

The 6th grade students presented the category 'water'. They incorporated many units here, because in these units water was a very important material to accomplish the goal of the science class. Despite water being used for various purposes in each unit, one common point to all units was that water was treated centrally when students learned the theme of each unit. Namely, students made the category in light of what they had experienced in their science classes. In comparing to the other categories, 'water' was, to some degree, more equally composed of the four branches. The unit 'dissolution and solution' in the branch 'material', the units 'the temperature and the wind' and 'the travel of water' in the branch 'earth', and the units of 'small living things' in the branch 'life' made up this category. In this point of view, 'water' would be considered as a concept which many branches could be integrated into.

Category 'Water' (5th)

Followed by the 6th grade students, the 5th grade students also presented the category 'water'. If the units had the any appearances of water or any activities dealing the water, these units were included in here. The reasons of creation of the category 'water' were originated by students' life or experiences. They suggest this category with the memories, experiences of the water in their life. The 5th grade created the 'water' category, heavily using units from the 'earth' and 'material' branches. This was caused by the contents of these units 'the fluid and our life', 'the river and the sea' and 'the water changing the appearance'. Studying 'water' could be a good topic to encompass the various phenomena of the branch 'material' and many natural phenomena.

Category 'Nature' (6th)

The category 'Nature' appeared at every grade. Students created the category 'nature', thinking about the natural environment. This category was mainly composed of the 'life' and 'earth' branches. In the case of the 6th grade, the branch 'energy' took 16.8% of the category 'nature'. However, the branch 'material' did not take the similar frequency, because the concepts handled in the 'material' branch, for example 'dissolution and solution', were very difficult subjects to be incorporated in this category. On the contrary, 'the travel of water' and 'the energy' units could be included in the category 'nature'. This result gave the question about what factors made students feel familiar with some scientific concepts and the category 'nature' originated by their own experience.

Category 'Nature' (4th)

The 4th grade students also presented the category 'nature' with the idea about natural environment and its inhabitants. The category 'nature' in 4th grade heavily composed of 'life' and 'earth' branches, like the other grades. 'The living things under water', 'the water carrying the earth', 'the leaf and the stem of plant' and 'the various stones and soil' made up the category 'nature'. On the other hand, the unit 'the one life cycle of a drosophila' takes only 1.1% of the category 'nature'. Students did not unconditionally include every unit of the branch 'life' into the

category 'nature'. This category included the units dealing with living things easily seen near students' environment. In relation to this, the unit 'the leaf and the stem of plant' took 22.2% of the highest frequency. It is possible that this is because plants are often encountered in their lives. It seems that students included something related to their natural environment in the category 'nature'. In the 4th grade, the category 'nature' was the environment of students from the science branches 'life' and 'earth'.

Category 'Fire' (6th)

The 6th grade students suggested the category 'fire'. They focused on the appearance of fire and linked it to other units. 'Fire' was mainly composed of the 'energy' and 'earth' branches. The units 'the energy' and 'the volcano and the rock' took 33.4% and 27.1% of this category respectively. This was a new distribution, because until now there had been no category composed of the branches 'energy' and 'earth' together. The unit 'the energy' commented the fire as one type of energy. In the unit 'the volcano and the rock', the appearance of an erupting volcano was related to the appearance of the fire. In the two units, the fire was not the main concept of student's learning. However, as it was interesting, it aroused students' curiosity and integrated 2 branches. Students' memory of 'fire' from the classes caused the category 'fire'.

Category 'Light' (6th)

The 6th grade students made the category 'light'. 'Light' was a subject capable of being incorporated into many units. Although, some units did not include any concepts of light, if they saw any interesting appearances of light in the classes, students inserted those units into this category. The branch 'energy' took 68.8% of the category 'light'. Particularly, units of 'making the electricity circuit' and 'energy' took 50.8% of this category. The reason for this was the experience using the light bulb when they carried out the experiment in the unit 'making the electric circuit'. Concerning 'the energy' unit, the memory of learning 'most of energy was handed from the sun and by the type of light' influenced that result. It showed the fact that learning concepts influenced how students make their categories. In the case of 'mirror and lens', which is the unit mainly comprising the subject light showed the lower frequency of 7.7% rather than a higher frequency. Despite 'the light' being one of the main subjects of this unit, most students put this unit into other categories, for different reasons. It was interesting that students essentially did not relate many activities in this light unit.

Category 'Season' (4th)

The 4th grade students presented the category 'season'. This 'season' was their environment including weather or temperature. The unit 'measuring temperature' that is from the branch 'energy' and 'the weather and our life' that is from the branch 'earth' made up the majority of this category. In this category, the branches of 'material' and 'life' took 12.9% and 17.7% of the frequency. This is because concepts such as temperature and weather are important factors that affect the performance of experiments included in the units 'the leaf and the stem of plant' and 'valuable air'. They can be linked with the category 'season'. Thus, this category showed the most balanced frequency of the 4 branches. The reasons of creation of the category 'season' were the student's own idea about temperature, weather and environment. Students did not consider the 4 branches of science when they made the domain of science they learned. However, students focused on scientific concepts relating to the environment which they have experienced.

Category 'Things for everyday life' (4th)

26.5% of the 6th grade students presented the category 'our life'. 23.4% of the 5th grade students presented 'The things that students think are necessary for everyday life'. 69.1% of the 4th grade

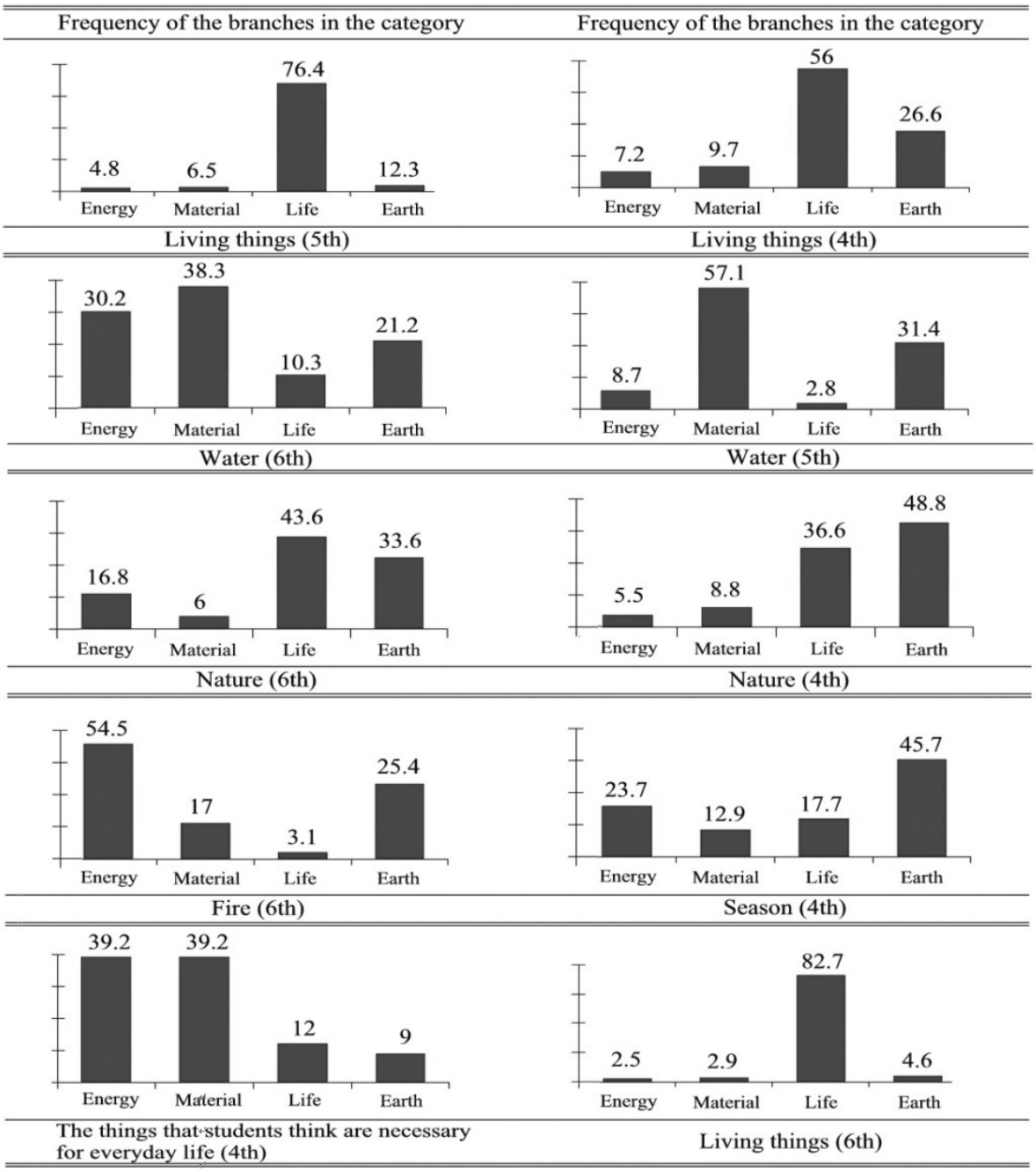

Fig. 8 *Categories by student's own thinking*

student presented the same category as above. In this category, the units are 'the material of our surroundings', 'measuring the temperature' and 'making a sound' showed the heaviest frequency. These units were 'energy' or 'material' branches while units from 'life' and 'earth' branches did not compose this category. This was opposite composing as compared to the category 'nature'. It showed students had the opposite characteristics of science domains of 'nature' and 'The things that students think are necessary for everyday life'. Students from every grade put

some scientific concepts from 'energy' and 'material' branches in to subordinate categories such as 'need for life' or 'the people use'. This meant that science domains of students generally were connected with their life. Also, this showed many scientific concepts can be classified by students' memory of the environment they experience and in which they live.

Ⅶ. Conclusions, Discussion and Further Researches

This study investigates the structural formation of the 7th Korean science curriculum with the focus on 4 branches. We devised the image cards made by each unit cover of the 7th Korean science textbooks in order to evaluate the characteristics of students' domains of science. The 4th, 5th and 6th grade elementary students were asked to classify those cards. In this research, students presented various categories for the purpose of classification. 30% of the 4th grade students created the following categories: 'nature', 'observation', 'season', 'living things', 'sound', 'separating' and 'The things that students think are necessary for everyday life'. Over 30% of the 5th grade created the following categories: 'living things', 'weight', and 'water'. Among the categories that were made by the 6th grade, over 30% of students created the following categories: 'nature', 'light', 'water', 'living things', 'solution', 'fire', 'properties of an object' and 'experiment'. Over 30% of students in all grades created these categories: 'living things', 'water', 'the things necessary for everyday life', 'nature' and 'light'. The most notable result was that 'living things' was created by 80.2% of all students.

Some categories ('Nature' and 'the things that students think are necessary for everyday life' and 'living things') appeared at every grade. However other categories were presented by only one grade. The categories showed little difference in characteristics when the age of student or the content of curriculum was considered. Generally, students classified the units of branch 'life' and 'earth' into the category of 'nature'. The units of branch 'energy' and 'material' were located in the category 'The things necessary for everyday life'. The category 'living things' was mainly composed of the units from the 'life' branch, and a little lower frequency of units of branch 'earth' compared to the other two branches. Concerning the categories 'water', 'fire', 'observation', 'nature' and 'season', they tended to keep the balance shown by the four branches.

Students' creation of the science domains (categories) appeared fundamentally in three main ways. First, students made the domains by the foundation of academic contents and concepts. The category 'living things' of the 6th grade, 'solution', 'properties of an object', 'weight' and 'sound' included in this first way. Those categories were difficult to connect with their life experiences or their environments. That is to say, it was a very specific concept for them. Thus, elementary students tended to make only one or two branches included here.

Second, students presented the science domains by focusing on the activities related to their science class. The domains presented in this manner were 'observation', 'experiment' and 'separation'. We anticipated that these categories would be more evenly distributed keeping a balance compared with the other categories, because all units of the 4 branches contained the scientific activities. In actuality, only one branch or one the other branch included in these categories because of the special appearance of an experiment recognized by students and their own particular expectations of a scientific activity.

The third style of producing domains related to their memory of experience, their life and personal environment. Students classified the image cards of units by giving a new value to the scientific contents in connection with their life. In this process, their personal environment and their own ideas about the scientific concepts made an effect on classifying the unit of each branch. The categories created through this method were: 'living things', 'water' of the 4th and 5th grade,

'nature' of the 4th and 6th grade, 'fire', 'light', and 'the things that students think are necessary for everyday life'.

The main point is that students integrated the scientific concepts by using their own principles. By those principles, the science domains of students were not connected with the 4 branches of science. Rather than, the principles related to the concepts they learned, scientific activities and students' personal environments and their own memories of experience.

What is the reasonable principle of an organized science curriculum? Historically, all of science curriculums had differing characteristics, in common with contemporary attitudes. However, the educational aims of these curriculums were always common to the human being and real educational value. When a curriculum is developed, the first step is to have the science education experts decide the contents. In this phase, they have to solve the problems related with the allocation of time to each subject. All of the science branches compete with the other subjects for the allocation of the finite amount of time available in a curriculum. In addition, the time given to each branch of science has been divided into equal amounts because experts in each branch (i.e. physics, chemistry, biology and earth science) could not reach agreement. Even though there are many other reasons of keeping the 4 branch system, we could not ignore the competition among the branches.

Regarding the above problem, there was no one, certain answer, but there could be suggestions to make an effective structure of science curriculum (Parkinson, 1994). Parkinson suggested 10 principles: Breath, Balance, Relevance, Differentiation, Equal Opportunities, Continuity, Progressions, Links across the Curriculum, Teaching Methods and Approaches, and Assessment. With this suggestion, it is helpful to suggest a basic educational principal as followings.

As developed and modified science curriculum for students, we did not consider anything about students' own science domain and the characteristics of each domain. If we think of importance of the learners' features, we must consider both their own domains, representing the learner's characteristics, and the order of those domains. This process concerns the creation of new scientific domains, and the vertical and horizontal structure of those domains. Thus, we need to discover the science domains students have and the manner in which to structure those domains in the curriculum.

Thus, the current balance of the science curriculum can be reorganized by using the student's science domains. New principles centered on the characteristics of students could change the traditional approach of equal balancing the 4 science branches.

Further Researches

Relation to the order of teaching the units in the 7th science curriculum, even though teachers had the right to change the order of the units in one semester and the ability to restructure their curriculum by considering efficiency and the suitable times for learning, in reality, many elementary school school teachers did not change the sequence of units. They typically taught each unit of science by following the sequence as written in the textbook.

In this strategic point of view, we could rearrange the number and the order of units according to students' characteristics in each grade.

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