Cases and Features of Abductive Inference Conducted by a Young Child to Explain Natural Phenomena in Everyday Life

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Abstract: The purpose of this study is to explore the cases and features of the abductive inference used by young children when trying to explain natural phenomena in everyday life. From observing a 5-year-old's daily activities with his family, and analyzing the data according to the criterion extracted from the form of abductive inference described by C. S. Peirce, a few cases where the child used abductive inferences to explain natural phenomena were found. The abductive inferences in the cases were conducted: (a) based on figural resemblance and behavioral resemblance (b) under the influence by individual belief and communal belief, then (c) resulted in new categorization accompanied by over generalization. Such features of the abductive inference showed the 'double faces'; sometimes encourages and sometimes discourages children's generating better scientific hypotheses and explanations. These results suggest that even young children use abductive inference to explain doubtful natural phenomena in everyday life, although we need to consider carefully with the double aspects of the features of abductive inference for the practical applications to the fields of science education. Finally, several suggestions and following studies for science education are proposed.

Key words: abductive inference, hypothesis generation, explanation of natural phenomena.

I. Introduction

In relation to the construction of scientific knowledge and concepts, three types of inference play an important role: *deduction, induction* and *abduction* (Anderson, 2000; Kwon et al, 2003b; Lawson, 1995; Newell & Simon, 1972). Among these inferences, researchers consider abduction in particular as being essential in generating hypotheses that are useful in extending scientific knowledge (Aliseda, 2004; Curd, 1980; Fischer, 2001; Hanson, 1961; Thagard, 1988).

Abduction, which was systematically conceptualized by C. S. Peirce (Murphey, 1961; Hanson, 1958), is a kind of creative process to induce a new discovery in science (Magnani, 2004; Paavola, 2004). Abduction has been said to be the only logical operation which introduces any new idea. While induction does nothing but determine a value, deduction merely evolves the necessary consequences of a pure hypothesis; that is, "all the idea of science comes to it by the way of abduction (Peirce: *CP* 5.145)". For instance, Kepler's explanation of the features of Mars' orbital and Galileo's discovery of constancy of gravitational acceleration are examples of scientific discoveries conducted by abductive inference. These discoveries were made neither by just mathematically evolving the necessary consequence of hypothesis (that is, deductive inference), nor by mechanically extracting a common factor from collected observation (that is, inductive inference). Rather, discoveries resulted through abductive inference that led the scientists to reach to the conclusions beyond the information in the prior data (Hanson, 1958, pp. 85-89).

Very little research exists in context of young children's knowledge construction in everyday life relating to science while significant research exists concerning the cases where great scientists (e.g., Kepler, Galileo, Newton) used abductive inferences to generate hypotheses then make their great discoveries during their inquiries (e.g., Hanson, 1958; Lawson, 2002; Myrstad, 2004). Many scholars have pointed out that children construct their own knowledge to interpret natural phenomena and that this knowledge influences how they construct new know-

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ledge in formal school science classes (Driver *et al,* 1985; Duit, 1991; Fleer & Robbins, 2003), even those classes including university students (Sherin, 2006). It has also been argued that children's prior knowledge is constructed in their early everyday life before entering formal school (Vosniadou & Brewer, 1987; Inagaki, 1992; Osborne *et al.,* 1983), and is not simply isolated ideas but rather conceptual structures which provide a coherent understanding of the world (e.g., Gilbert *et al.,* 1982; Osborne & Freyberg, 1985; French, 2004). That is to say, children, even young children, are "interested in a wide variety of objects and events in the world around them" (Osborne & Freyberg, 1985, p.1) as like scientists, and attempt to make sense of the world "in an orderly fashion towards the construction of an initial framework theory of physics that allows children to function adequately in the physical environment" (Kaufman *et al.,* 2000, p. 7), since they were born and started to interact with the environments such as pulling their parents' hair, taking a stick, and pushing away a toys, etc (Andersson, 1986). Children's effort to explain natural phenomena and then construct scientific knowledge might happen not only at formal school, but also in the home in everyday life. In addition, the extension of scientific knowledge might happen to not only a few great scientists but also even young children as well as students, indicating that abduction might play a certain role in children trying to explain natural phenomena. Thus, it would be worthwhile to explore whether young children actually use abductive inferences to explain natural phenomena in everyday life and, if so, to identify the features of abductive inference conducted by young children. Such a study would give us useful data for devising particular strategies to teach science to young children and encourage elder students to construct their scientific knowledge with generating sound hypotheses.

Within South Korea alone, a significant number of science educational studies related to abduction exist, including studies of the process of hypothesis generation and its practical applications (e.g., Kwon *et al.,* 2003a; Jeong *et al.,* 2005; Joung & Song, 2006a; Oh, 2006; Park & Kang, 2006), the theoretical aspects of abduction (e.g., Kwon *et al.,* 2003b; Joung & Song, 2006b; Oh & Kim, 2005; Park, 2000), and cases of professional scientists' abduction (e.g., Yang *et al.,* 2006). However, most of these studies only consider cases of Grade 3 and above; furthermore, these studies consider only formal school experiences, not young children's everyday life experiences.

Therefore, this study aims to explore the cases and features of the abductive inference used by young children while trying to explain natural phenomena in everyday life. For this purpose, data was collected through the observation of a 5-year-old's daily activities with his family in order to analyze the data according to the form of abductive inference described by Peirce, and to illustrate and discuss the features of the abductive inference conducted by the child.

II. Research Design

1. General Settings and Subjects

The focusing questions of this case study are as follows.

(a) Are there cases where a young child uses abductive inference while trying to explain natural phenomena in everyday life?

(b) If so, what are the features of the abductive inference used by the young child?

This study was conducted based on a young child's daily conversations and activities at home. Home is the place where young children could have the vast and qualitatively rich conversations related to science in comparison with other formal places such as formal school, kindergarten. They ask numerous questions at home such as "What happens to toast?", "Is it melting?", "What would happen to the potato if it got really hot?" etc., while children do not ask any questions at the formal center (Fleer, 1996). This is the reason why the author meant to analyze daily conversations and activities which happened at home relating to science topics. As subjects of the study, the author's family was adopted under their permission. The reason for this adoption was that it could be possible to observe daily conversations and activities in depth and continuously. The author, therefore, was a participant as well as an observer in this study.

A 5-year-old (exactly 4 years and 10 months at the beginning of this study), referred as *E*, is the main participant in the study. At the start of the study, *E* had been attending a kindergarten for about two years. He could communicate with spoken language and sometimes in writing, and could carry out simple numerical summations and subtractions. He could also play simple games according to the given rules, such as card games. *E* liked to read children science books and to watch TV programs for children related to science. *E*'s mother, referred as *M*, had been teaching pupils at elementary school in Seoul, South Korea, for about 11 years. Although *M* taught all the subjects of the elementary school curriculum, she was interested in literature and art education rather than science and mathematics *E*'s father, referred as *D*, had been teaching pupils at primary school in Seoul for about 13 years, and possessed a PhD degree in science education.

2. Data Collection and Analysis

From the daily conversations and activities of *E* and his parents during 11 weeks, 29 episodes related to science topics were recorded in written form and sometimes on video. It was very difficult to record these episodes with any technological tools such as cameras, audio, video recorder because most conversations and activities happened unexpectedly. In addition, these technological tools attracted *E*'s attention, and then made the conversation and activity cease or change. As a result, the cases which happened unexpectedly were recorded in written form (i.e., field notes by hand) (Merriam, 1988) during or right after the happening; however, a few cases that could be expected to happen were recorded by video camera.

The data was analyzed according to the form of abductive inference described by Peirce. Peirce highlighted two properties of abductive inference: (1) abductive inference makes it possible to regard the present doubtful/strange phenomena as one case of the prior general rule based on the resemblance between the phenomena and the rule (Peirce: *CP* 2.621-624); (2) abductive inference makes it possible to change someone's psychological state from 'doubt' to 'belief' when this person meets doubtful phenomena (Peirce: *CP* 5.189, 5.374).

Peirce conceptualized abductive inference comparing

[Deduction]

Rule — All the beans from this bag are white
Case — These beans are from this bag
∴Result — These beans are white
(Deductive or Analytic)

[Induction]

Case — These beans are from this bag
Result — These beans are white
∴Rule — All the beans from this bag are white
(Induction)

[Hypothesis(Abduction)]

Rule — All the beans from this bag are white
Result — These beans are white
∴Case — These beans are from this bag
(Abduction)

(Synthetic)

(Inference)

Fig. 1 *The types of syllogism and inference categorized by Peirce (Based on CP 2.623)*

two other inferences, deduction and induction, as shown in Fig. 1. Deductive inference is merely the application of general rules to particular cases. In deductive inference, for example, major premise lays down general *rule (*e.g., *All the beans from this bag are white),* and minor premise states *case (*e.g., *These beans are from this bag),* and then *result (*e.g., *These beans are white)* is derived by applying the rule to the case. Therefore, deductive inference is often called as analytical inference. Both inductive and abductive inferences are synthetic inference in respect of producing something beyond the information incorporated in the premise, although there are certain differences between them. Inductive inference infers rule from case and result; however, abductive inference infers *case (*e.g., *These beans are from this bag)* from *rule (*e.g., *All the beans from this bag are white)* and *result (*e.g., *These beans are white)* according to resemblance between the result and the *rule (*e.g., *are white)* (Peirce: *CP* 2.621-624). That is, abductive inference is "where we find that in certain respects that two objects have a strong resemblance, and infer that they resemble one another strongly in other respects" (Peirce: *CP* 2.624).

Eventually, abductive inference makes it possible to regard the present doubtful/strange phenomena as one case of the prior general rule based on the resemblance between the phenomena and the rule. This feature of abductive inference makes someone feel stable in the 'belief state' because the doubtful phenomenon becomes a matter of course under the pre-accepted rule (Peirce: *CP* 5.189). For instance, "Fossils are found; say, remains like those of fishes, but far in the interior of the country. To explain the phenomenon, we suppose the sea once washed over

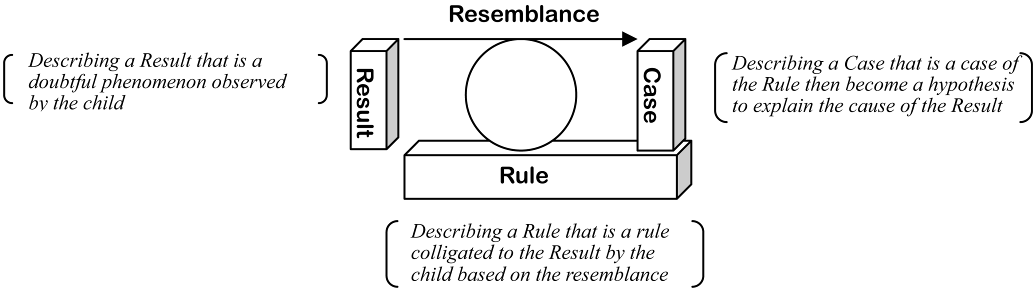

Fig. 2 *'Model for describing Abduction Process (MAP)' and its application to this study*

this land." (Peirce: *CP* 2.625). That is to say, abductive inference is the logic that makes a doubtful/strange phenomenon believable/ordinary by supposing the phenomenon as one case of more general rule according to the resemblance between the phenomena and the rule.

Concerning as this study, such features of abductive inference could be expressed by the describing model; 'Model of describing Abduction Process (*MAP)*' (see Fig. 2). The *MAP* was developed by the author on the basis on the Peircean view of abduction that is the process of state transforming from 'doubt' to 'belief' through the 'rule → result → case' type inference as mentioned above. In Fig. 2, 'Result' stands for doubtful phenomenon observed by someone, and 'Rule' for prior gneral rule, and 'Case' for explantory hypithesis as a result of abductive inference. The circular arrow stands for the consideration with resemblance between the Result and the Rule. The position of each constituent stands for whether it stands at unstabe state (Result) or stable one (Case). The three blankets was designed to help analyizing the data and describing the results of this study.

Considering the features of abductive inference mentioned above, the data was analyzed according to following three criterions:

- Is it the case related to natural phenomena or science topic?
- Is there a process where the child meets a doubtful phenomenon then tries to change his psychological state from the one of doubt to belief?
- Can the process of the child's inference be regarded as the one by comparing resemblance between the present phenomenon and the rule the child knows (i.e., the logical form described by Peirce, as illustrated in Fig. 1)?

Examining the 29 episodes, the cases that satisfied all of three criterions above were adopted as being representative of instances where abductive inference was conducted in order to explain natural phenomena. Additionally, the cases were examined and confirmed whether they satisfy all three of the criterions by two experts, the first a major in science education focused on conceptual learning, and the other a major in philosophy of education focused on Peircean abduction. When it was necessary to examine what the rule the child already had known was, sometimes, supplementary interviewing the participants or exploring the corresponding parts of the other episodes were conducted. As a matter of convenience for the analysis and description, the *MAP* (see Fig. 2) was used as well. Based on the results of the analysis, the features of the adopted cases were illustrated and their implications for science education were discussed.

Ⅲ. Results and Discussions

1. The Cases of Abductive Inference

Are there cases where a young child uses abductive inference while trying to explain natural phenomena in everyday life? Analyzing on the daily episodes according to the three criterions, at least, three cases where the child used abductive inferences to explain natural phenomena were found as follows.

Case 1: 'This rubber band is a keyboard (of a guitar)'

E explained the cause through abductive inference while he was trying to find out the reason why the tightened rubber band made sound. One day, *E* was playing with a pair of tweezers, a chisel for trimming nails, and yellow rubber bands. He repeated the playing the acts of lifting the rubber bands and releasing them with tweezers and a nail-trimming chisel. After doing it for two or three minutes, he started to fix them onto the drawers' handles of TV case. After extending the rubber bands with the nail-trimming chisel, he affixed the other ends to the handles of the other drawers. He struck the tightened rubber strings with nail-trimming chisel and started to play. He listened to the sound it makes and struck the rubber strings of both ends by turns and repeated the acts for three or four minutes. As the rubber strings were fixed to the two handles of the drawers, the rubber strings became a shape of long ellipse and the extent of tension between two sides was different. Dad, who had been watching him, said to him as follows in Excerpt 1.

Excerpt 1

01 ***D***: Do you know why this makes sound?
02 ***E***: .... (*E thinks*)
03 ***D***: How do you think this makes sound?
04 ***E***: .... (*Without any words he keeps on striking strings*)
05 ***M***: Pleas think why this produces sound.
06 ***E***: When I do this with only one, I can't find why, but when I do with two, (*It means when he plucks strings of both right and left side one*) it is like keyboard, like a guitar or violin. (*He continued to make sound by plucking the rubber strings*)
07 ***E***: This is a low note, that is a high note. A guitar…. Originally this…. (*He was about to say something, when a rubber string came off flying*) Wow! Wow! It is a rocket. (*He again affixes a rubber string and holds the chisel in one hand, the tweezers in other hand.*)
08 ***E***: I am going to do it again. Getting two things ready, I can pluck freely. (*With the chisel, he plucks the rubber string as if he plays the violin and moving fast from side to side, plucking strings at the same time*) It is OK if I strike freely.
09 ***D***: In what way do you think they make sound?
10 ***M***: Why does it make a high sound?
11 ***E***: I don't know.
12 ***M***: What do you think is the cause?
13 ***E***: I think these become keyboards.
…

(Excerpted from Episode [19])

As shown in the above excerpt, *E* had not known the reason why the tightened rubber band made sound at first. It was too difficult for him to answer immediately to the parents' question. After thinking for a minute, however, he made an explanation in his own way, "I think these become keyboards", in turn 13. Why did he think like that? We can find out the reason in turn 06, "… it is a like keyboard, like a guitar or violin." That is, for *E*, 'keyboard' has a special meaning as a tool of making sound, at least, when the musical instrument having some strings such as a guitar, a violin, and so on. Furthermore, his attention to the superficial similarity between the tightened rubber band and a guitar was shown again in his picture of a guitar drawn during the supplement interviewing about the first arising situation in his mind when he hears the word 'a guitar' (see Fig. 3)—such a method has been used to examine students' ideas of science concepts in several previous researches (e.g., Jung & Song, 2004; Kang, 2006). He said that "When I do this with only one, I can't find why, but when I do with two … it is a like keyboard like a guitar or violin" (turn 06). Why did he say that the rubber band was like a guitar only when the strings were *two, not one*? As shown in Fig. 3, his picture of a guitar shows that the numbers of strings were extremely highlighted, although not the same as the real shape of a guitar. Eventually, he paid attention to the similar shape of the rubber band and a guitar, particularly, in respect of having strings above two.

From the perspective of adults who of course know that the word 'keyboard' is 'just the name' for a part of particular instrument rather than the theory and mechanism for making sound, *E*'s answer is not an proper explanation of the cause of making sound, but just an expression requiring another question

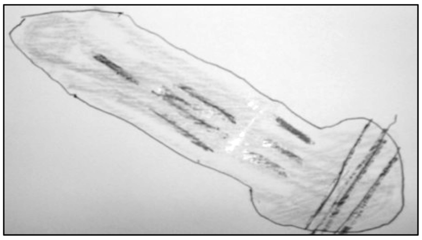

Fig. 3 *E' picture of a guitar he first thought of when he heard the word 'guitar'*

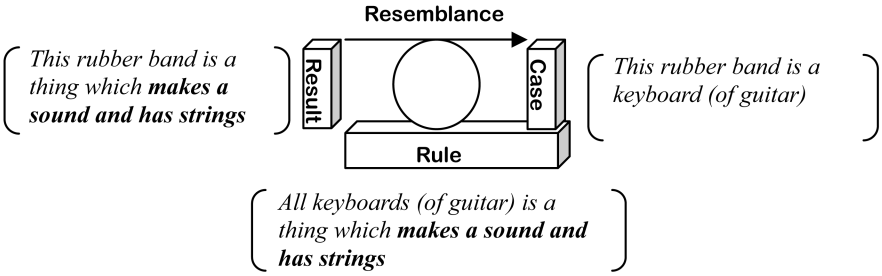

Fig. 4 *MAP of 'This rubber band is a keyboard (of a guitar)'*

such as "why does the keyboard make sound?". However, this explanation was useful for *E* to solve his doubtful problem, and even to explain the reason why different sound tone happened, as shown in turn 07, "This is a low note, that is a high note. A guita r…. Originally this…". In other words, in his own way, he could explain well the doubtful phenomenon, i.e., the rubber band making sound, by regarding the rubber band as a keyboard of a guitar based on the resemblance between them. In summary, *E*'s inference conducted in Excerpt 1 can be described as an abductive inference, as shown in Fig. 4.

Case 2:'The moving leg in the water is a picture'

Another case of E explaining a doubtful phenomenon by abductive inference was found while he was trying to find out the reason why the leg in the water (of bath tube) look like the leg was moving by itself freely, as described in Excerpt 2. One day, E was having a bath with Dad in the tub. They sat face to face, having a good time by pushing water to each other. At that time, he asked suddenly, as follows.

Excerpt 2

01 ***E***: Dad, how is it that your leg is so free?
02 ***D***: Sorry?
03 ***E***: Dad, what I mean is how does it happen that your leg moves as water goes by though your leg stays motionless?
04 ***D***: Ah...! (*He tries to stir water*) when I do like this?
05 ***E***: By the way, I didn't mean that. I just wanted to say it looked like that.
06 ***D***: Did you? Yes, it happens when I do this way. (*Stirring water with his hands*) As I do like this, my leg appears to be moving. In fact, I don't move my leg. How come?
07 ***E***: How does it really happen?
08 ***D***: How does it happen? How does it happen?
09 ***E***: Isn't it just like a picture?
10 ***D***: What did you say?
11 ***E***: (*sprinkling a cup of water to Dad suddenly*) Pshaw! Ha, ha....
12 ***D***: How does it happen?
(*The conversation was stopped as E played splashing water all over. They resumed bathing. After five minutes or so of bathing, E had a jolly time playing with cups in the water such as sitting on them and then gave a question to Dad.*)
13 ***E***: Dad, by the way, (*thrusting a cup into the water*) how does the cup look smaller when I do like this?
14 ***D***: Er⋯ It is really true. Why does it look smaller?
15 ***E***: Look! It does really become smaller, doesn't it?
16 ***D***: Why is it so? Why does the cup look smaller?
17 ***E***: This is totally unreasonable and a nonsense. It is⋯ it is just like a picture, visible only to the eyes.
18 ***D***: You said it is like a picture? What do you mean by it?
19 ***E***: What I mean is it is not real, but it is a picture looking so to the eye.
20 ***D***: Well, how does the picture look so?
21 ***E***: Wow! (*He starts again sprinkling water*)
(*The dialogue was stopped again. No mention came up during the bath concerning the subject mentioned above.*)
(Excerpted from Episode [04])

E wondered about the reason why *D*'s leg moved freely as water goes by although *D*'s leg stays motionless as shown in turn 03. Of course, for a physicist, this phenomenon should be illustrated with refraction theory, considering the difference of density of water and air, movement of water, etc. Although not appropriate to physics theory, however, *E* tried to explain cause of this phenomenon by comparing it with something he knew already considering with resemblance between them. The something was a picture to him. He knew that *D*'s leg did not move

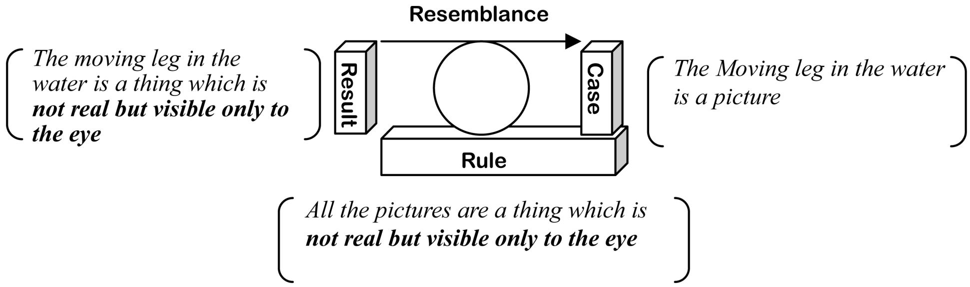

Fig. 5 *MAP of 'The moving leg in the water is a picture'*

really though looked like moving, as shown in turn 05; "By the way, I didn't mean that. I just wanted to say it looked like that". For him, the thing which is not real though looks real is "… a picture, visible only to the eyes" (turn 17). Therefore, he explained that the phenomenon, i.e., *D*'s leg is free, was just picture. By explaining like this, he could arrived at a stable state under his prior rule that picture is not real but visible only to the eye. The same explanation and process was found while he was trying to illustrate the reason why a cup in the water became smaller than in the air, as shown in turn 15 – 19. *E*'s inference shown in the excerpt 2 can be described by the *MAP* (see Fig. 5).

Case 3: 'Electricity is a machine'

The following excerpt is another example of *E* using an abductive inference. One day, while having a breakfast, the TV showed an advertisement for a detergent used in a dishwashing machine. *E*'s questions started when he thought that the detergent for a dishwashing machine, not the actual dishwashing machine, washes automatically by itself. He felt strange, and tried to explain it based on the resemblance between a detergent and a machine, as shown in Excerpt 3.

Excerpt 3

01 ***E***: Mum, we have that at our home, don't we?
02 ***M***: Ha, ha. Yes, you know everything.
03 ***E***: When the detergent is put into the dishwasher and gets mixed around, the washing is done, isn't it?
04 ***M***: Yes, you are right.
05 ***E***: Is that a machine, too?
06 ***M***: Uh?
07 ***E***: Is that also a machine?
08 ***M***: What is a machine?
09 ***E***: It is a thing which is moving and working by itself. Isn't it one of them?
10 ***M***: Yes, you are quite right. However, we have different cases. If I hang the laundries on the line, they dry up by themselves, don't they? It is not because of the machine, but because of the power of the sun.
11 ***E***: Emm. You are right. But isn't a washing-machine a machine?
12 ***M***: Yes, we mean by machine that it has some physical body, like a washing-machine.
13 ***E***: Electricity is a machine, isn't it?
14 ***M***: Electricity?
15 ***D***: How did you think that electricity is a machine?
16 ***E***: ... (*He watches TV without words*)
17 ***M***: *E*, you can tell whatever under no pressure. Don't mind if you are wrong. Why do you think electricity is machine?
18 ***E***: ... (*He keeps on watching TV without words*)
19 ***M***: Is electricity machine?
20 ***E***: (*Suddenly he opens his mouth*) Of course, it is.
21 ***M***: Why?
22 ***E***: It moves by itself. When electricity enters, it moves automatically.
23 ***D***: Hmm. Give me an example.
24 ***E***: Hmm. Hmm. (*He ponders for about five seconds*)
25 ***D***: Er, for an example, is it something like TV set?
26 ***E***: (*His eyes are getting round*) Therefore, it is something like 'Intelligence Development Model'. (*It is a toy similar to a Science Box*) When it is turned on, it moves and gives light as well. I can say something like a radio.
27 ***D***: How about controlled car?
28 ***E***: Yes, it is, too.
29 ***M***: Ah, you mean you come to conclusion that electricity is machine, don't you? You are very clever.
…

(Excerpted from Episode [15])

As shown in the above excerpt, *E* thought, "When

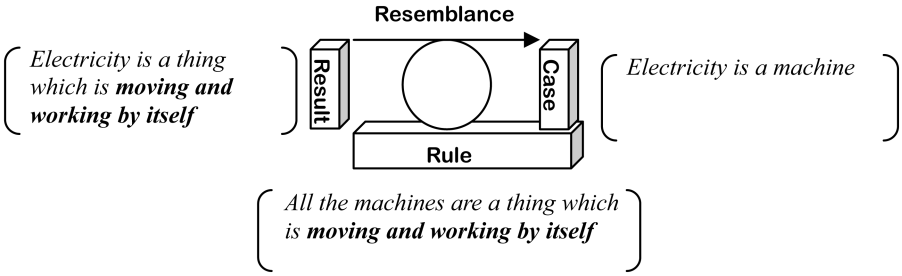

Fig. 6 *MAP of 'Electricity is a machine'*

the detergent is put into the dishwasher and gets mixed around, the washing is done" (turn 03) automatically, and that a machine is "a thing which is moving and working by itself" (turn 09). In his view, therefore, the detergent for a dishwashing machine is a machine (turn 09) as well because the detergent has a feature, i.e., moving and working by itself, then has some resemblance with a machine. His inference like this was found again while he was talking about electricity. He tried to classify electricity into a machine as well, as shown in turn 13; "Electricity is a machine, isn't it?". When his parents asked him, "Why do you think electricity is machine?" (turn 15, 17), after pondering for a minute, he suddenly answered that "Of course, it is." (turn 20), because "It moves by itself. When electricity enters, it moves automatically." (turn 22). It can be said that his decision like this was conducted based on the inference considering with the resemblance between electricity and a machine. In addition, he was very pleased to explain and take other examples well because of such inference, as shown in turn 26 – 28. Eventually, the inference used in his explaining electricity and a detergent as a machine can be described as abductive inference, as illustrated in Fig. 6.

2. The Features of the Abductive Inference Founded in the Study and Their Science Educational Implications

As described above, even young children sometimes use abductive inference to explain doubtful natural phenomena in everyday life, although the results of this study are just one child's cases. If so, what are the features of the abductive inference conducted by a young child? The abductive inferences conducted by the child, at least, in this study showed '*double faces*'; '*based on figural resemblance and behavioral resemblance*', '*influenced by individual belief and communal belief*', '*result in new categorization and over generalization*'. One aspect of double faces sometimes seems to stand with the other as a supplementary and sometimes as an obstructer. Such a feature of abductive inference sometimes encourages and sometimes discourages children's generating better scientific hypotheses and explanations, as follows.

Based on Figural Resemblance and Behavioral Resemblance

The abductive inference by the child in this study was conducted based on the 'behavioral resemblance' between the Result (observed phenomenon) and the Rule, which refers to the resemblance in respect that how they work, as well as the 'figural resemblance', the resemblance in respect that what outer shape they have. For example, as shown in Excerpt 1, *E* explained the reason why the rubber band makes sound by regarding it as a keyboard of a guitar based on its similar shape with a guitar, particularly, in respect of having strings more than two. This case is saying that the abductive inference was conducted based on the figural resemblance. On the other hand, the cases described in the Excerpt 2 and 3 are showing that the child used abductive inference based on the behavioral resemblance as well. In Excerpt 2, *E* was paying attention to the similarity between 'moving leg in the water' and 'a picture' in respect of both 'not being real but visible only the eye'. That is to say, he found out the resemblance of them by paying attention to the aspect that how they work instead of the outer shapes of them. Such attention to the behavioral characteristics is shown more clearly in Excerpt 3 where *E* regarded both electricity and a detergent as a machine based on their common characteristics of 'moving and working by themselves' even though there are ontological differences between them as well as figural differences. The fact that there are different kinds of attentions concerning resemblance was argued also in some previous studies of children's analogical problem solving (e.g., Chen, 1996; Chen & Daehler, 1992; Crisafi & Brown, 1986). These studies have illustrated that children can transfer successfully analogue solutions solving new problems based on various similarities such as a superficial similarity related to surface commonalities, a structural similarity defined as the similarity of the casual relations among key problem elements, and so on.

The problem of which aspect of the phenomenon children would heavily consider with seems to be another task, insofar as this choice would influence the conclusions of their abductive inferences. For example, if *E* heavily had considered the behavioral aspect of the rubber band, i.e., 'vibrations of string', he might have found another Rule or other resemblance then might generate another explanation. Similarly, if he had carefully paid attention to the figural difference between electricity and a machine even beside ontological difference between them, he might have arrived at another conclusion. Of course, as argued by Peirce (Peirce: *CP*. 2.624), the process of paying attention to the resemblance between two objects in certain respect and inferring that they have the resemblance in other respect is the inherent process of abductive inference. However, in order to not just describe the process of abduction, but to develop a means whereby children and students could be led to generate better hypotheses and explanations, it appears to be required to complement the process of abductive inference with the results of the studies related to analogical problem solving, such as students' failure to map, over-mapping error, miss-mapping error, rash-mapping error etc. (e.g., Else *et al.,* 2003; Kim *et al.,* 2006).

Influenced by Individual Belief and Communal Belief

The cases of this study showed that the abductive inference of the child was conducted toward and influenced by a communal belief consented by a community as well as an individual belief. Abductive inference is a logical tool makes someone to recover his or her psychological state of 'belief' from 'doubt' induced by strange phenomena (Peirce: *CP* 5.189, 5.374, 2.624). In addition, concerning the concept of belief conceptualized by Peirce (see Joung & Song, 2006b), 'cessation of doubt' can be regarded as one of the necessary conditions for the belief (Peirce: *CP* 5.372, 5.375). All of the cases, first above all, showed that the child dissolve his doubt with the abductive inference then arrived at the state of belief in his own way, that is, individual belief. *E* was able to account the cause of the strange phenomena then to dissolve his doubt, at least in his thought, by abductive inference although his explanation might not be correct in a view of the corresponding science theory, as shown in the Excerpt 1, 2, and 3. These cases can be regarded as practical examples of 'layers of explanation that make someone satisfy him or her with', as discussed theoretically by Joung & Song (2006b). At the same time, it was also found that the child continuously interacted with other people's beliefs. This feature of the child's abductive inference was shown clearly in Excerpt 3. In the Excerpt 3, *E* hesitated to give a decision and explanation when he met with *M*'s doubts about 'how detergent and electricity can be regarded as a machine' (see turn 08 – 12, 16 – 18), and he confirmed his explanation with pleasure because *D* agreed on his explanation (see turn 25 – 28). That is, the communal belief of the family continuously affects the process of dissolving *E*' doubts.

The existence of the influence of a communal belief suggests that we should pay attention to the role of community as well in generating scientific hypothesis and explanation although the cases are showing that *E* ceased eventually from doubting the given phenomena depending on the state of individual belief. This view has a thread of connection with the sociocultural view where children's scientific knowledge construction is not regarded as an isolated work from social and cultural environments (Lemke, 2001; Robbins, 2005; Vygotsky, 1978). In sociocultural view of science education, therefore, science learning should not be regarded as just a procedure of individual mental process but as participation and enculturation in the process constrained by social and cultural context (Aikenhead, 2006; Rogoff, 1998). Peirce, too, stressed the role of community in exploring the truth with continuously considering practical effect of an object (*CP* 5.311, 5.387) although he alerted to the limits and dangerous influences of the over-authority of community (*CP* 5.381). The cases in this study provide examples of interaction between an individual and a community through the inference of which purpose is to attain certain belief incorporated in both of them.

Result in New Categorization and Over Generalization

The cases of this study showed that the abductive inference of the child led him to make a new categorization accompanied by an over generalization. For example, in order to explain doubtful phenomena, E pursued to seek the resemblance between present phenomena and something prior, and then eventually he categorized ‘a rubber band’ as ‘a keyboard of guitar’ (see Fig. 4), ‘moving legs in the water’ as ‘a picture’ (see Fig. 5), ‘Electricity’ as ‘a machine’ (see Fig. 6). These were new categorization. A rubber band had never been categorized as a keyboard until he tried to explain why it made sound. ‘Moving legs in the water’ had never been categorized as a picture until he tried to explain the reason why his father’s legs move as water goes by though his father’s legs stay motionless; neither had been electricity. That is, the cases of this study showed that the abductive inference led the child to categorize newly the present natural phenomena.

This feature of ‘new categorization’ is related to conceptual learning of science as well. What is ‘concept’? Many scholars have agreed that one of the natures of concept is ‘categorization’ (e.g., Gilbert & Watts, 1983; Howard, 1987; Medin, 1989; Thagard, 1992) although there is no single definition consented. Of course, there are various models to explain the mechanism of the categorization. For instance, in the view of the prototype model and the exemplar model, concept is regarded as something to do categorization by considering with the similarities between an object and a prototype, which refers an abstract type of mental representation extracted from a group of objects where the object belong as a member (Rosch, 1978; Rosch & Mervis, 1975), or a exemplar, which refers a mental representation that is an actual and specific example corresponding to the object rather than an abstract form (Brooks, 1987; Medin & Schaffer, 1978). The theory-based model, which is another model for describing the mechanism of categorization, has claimed that “classification is not simply based on a direct matching of properties of the concept with those in the example, but rather requires that the example have the right ‘explanatory relation’ to the theory organizing the concept” (Medin, 1989, p. 1474). However, such models have the common base: concept is a kind of mental representation carrying out categorization. Insofar as concept inherently has the role of categorization, ‘conceptual change’ can be regarded as ‘categorization change’. Thus, abductive inferences in the study lead *E*’s conceptual change in respect that one of the natures of concept is categorization and the *E*’s new categorization by the abductive inference accompanies by a kind of ‘branch jumping (Thagard, 1992, p.36)’, which involves a jump of a concept from one branch of the conceptual tree to another, as shown his reclassification ‘electricity’ as ‘a machine’.

At the same time, the cases showed that *E*’s new categorizations did not always connect good explanations with scientifically correct concept and theory. It appears that such results come from ‘over generalization’ happen under, for instance, the influence of the state of individual belief accompanied by emotional judgment, the too heavy intention on certain partial resemblance, etc. Over generalization, of course, has been known as an important cognitive skill that makes it possible for humans to construct the whole figure and meaning of an object from the insufficient information, such as the case of deciding an animal as a tiger after seeing only its big and black striped tail (Hinton *et al.,* 1986). Furthermore, over generalization seems to be inherently imbedded in abductive inference. Abductive inference is a logic that “amplifies, or goes beyond, the information incorporated in premise (Magnani, 2004, p. 222)” by inferring two objects resemble one another strongly in other respects when they show a resemblance in certain respect (Peirce: *CP* 2.624) then lead someone to attain the state of belief (Peirce: *CP* 5.189). This means that abductive inference must involve the process of over generalization. In other words, paradoxically, in some respects abductive inference cannot avoid being conducted by over generalization and require rooms for over generalization in making a hypothesis if we want to make a better one. However, insofar as one of the purposes of science education is to lead children and students to construct a more scientific hypothesis, explanation, and knowledge, we should not ignore the results that *E*'s abductive inference in everyday life led his misconceptions in regards to corresponding scientific theory. Furthermore, it appears that such over generalization obstructs the continuously examining the relevance of the present hypothesis and reconsidering with the present natural phenomena. Although young children try to do various things other than just inferences in order to construct scientific knowledge (Joung, 2006), such overgeneralization might make *E* remain standing on his present conception that is insufficient to scientific view. That is to say, the cases in this study are saying that we need to give attention to both sides of the features of abductive inference as the efficient strategy for students' conceptual learning at the one side and as the one of the causes to induce their misconception at the other side.

IV. Conclusion and Suggestions

This study aimed at exploring the cases and features of the abductive inference conducted by young children when trying to explain natural phenomena in everyday life. From observing a 5-year-old's daily activities with his family and analyzing the data according to the form of abductive inference described by Peirce, a few cases where the child used abductive inferences to explain natural phenomena were found. The abductive inferences in the cases were conducted: (a) based on figural resemblance and behavioral resemblance (b) under the influence by individual belief and communal belief, then (c) resulted in new categorization accompanied by over generalization. Such features of the abductive inference showed the 'double faces'; sometimes encourages and sometimes discourages children's generating better scientific hypotheses and explanations. In conclusion, this study suggests that even young children use abductive inference to explain doubtful natural phenomena in everyday life, although we need to consider the double aspects of the features of abductive inference for the practical applications to the fields of science education.

Although we need to be cautious of the limit that this study is a case study of one child, the results of the study give several suggestions as follows. Firstly, the result that even a young child uses abductive inferences to explain strange phenomenon in everyday life then arrives at new categorization suggests that we should not ignore the possibility of the scientific inquiry including hypothesis generation in the early childhood science class. According to the results of the previous study of investigating secondary school science teachers' perception about hypothesis generation in Korea (Kim & Kang, 2006), about 80% of participants thought that hypothesis generation is not possible to be conducted by children below Grade 3. However, insofar as the abductive inference can be regarded as the process to generate hypothesis, the results of this study are showing that hypothesis generation could be practiced in the science class of the lower grades of elementary school and even in the class of kindergarten as well, although it might be required some modifications for applying practically to the class; for instance, using the guided form following the step of Peircean abduction instead of asking to generate hypothesis directly with the terminology 'hypothesis', as suggested by Joung & Song (2006a).

Secondly, the features of the abductive inference in the study suggest that we should give attention to more various regions to utilize abductive inference for better science learning including more scientific hypothesis generation and conceptual learning. For example, we should pay attention to the results of the work in the field of analogical problem solving strategies for science learning (e.g., Else *et al,* 2003; Kim *et al.,* 2006) in order to lead children to find out more relevant resemblance. In addition, we should try to make a connection between such results and the results of the studies about the rule-inferring strategies for abductive inference (e.g., Oh, 2006) to help children with generating hypothesis more effectively. With this, in order to reduce the side effects of over generalization and lead children to explain natural phenomena more scientifically through adopting better hypothesis, we should pay attention to developing of the methods to make children conscious of the present phenomenon for long time and continuously reconsider with it in various respects. Insofar as two states, i.e., the state of doubt and belief, influence the process of abductive inference, we should also connect the state of belief with the results of studies about the emotions related to scientific inquiry and the methods of examining them (e.g., Shin & Kwon, 2006). In addition, if it is possible to carry out in-depth studies about the interactions between an individual belief and a communal belief and their changes, the more useful strategies for scientific hypothesis generation accompanied by knowledge construction might be given from the viewpoint of sociocultural approaches as well as individual mental process approaches. Perhaps, considering the interaction between the two beliefs shown in this study, we might come to highlight the 'group-type generation of hypotheses' generated by not only an individual independently, but together with the other constituents of a concerned community.

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