# An Investigation on Models of Making-hypothesis Process by Analysis of Formulating Hypotheses on Repetition Hypothesis Activities in Middle School Students

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## ABSTRACT

The scientific inquiry enterprise consists of formulating hypotheses, testing hypotheses, evaluating evidence, and revising hypothesis. Scientific inquiry in the science classrooms requires students' background experience and knowledge with the phenomenon in order to ask appropriate questions, identify and define variables operationally, formulate hypotheses, and design clear and complete experiment. The ability to test hypotheses has been postulated to play a central role in cognitive processes. The purpose of this study was to analyze what the change of the quantity and quality of the hypothesis, the rejecting or accepting of the hypothesis, and the use results in the repetitional hypothesis activity experiments. To examine the problems, this study analyzed 5 classes which were designed and administered to 16 students of the 7th grade. The results of this study showed that students preferred the engineering method to scientific method and the quality of a second hypothesis got low. The quality of the hypothesis came to be higher through a repetitional hypothesis and the number of hypothesis was reduced. The results of the experiments did not play central roles in revising hypotheses and accepting or rejecting hypothesis.

**Key words**: making-hypothesis, repetition hypothesis scientific inquiry, revising hypothesis, rejecting or accepting of hypothesis

## Ⅰ. Introduction

A generally acknowledged purpose of science education instruction is to help students develop scientific thinking abilities (Educational Policies Commission, 1966). Science inquiry in the laboratory can help students develop reasoning, higher-level thinking, and science processes (Germann, Odom, Aram, & Burke, 1996b). Scientific inquiry in the classroom requires background experience and knowledge of the topic being discussed so that one can ask the appropriate questions, identify and operationally define variables, formulate hypotheses, and design clear and complete experiments (Klahr, Fay, & Dunbar, 1993). In science education, classroom studies of scientific thinking focus on the basic and integrated science process skills as key elements in an inquiry. The scientific inquiry enterprise consists of formulating hypotheses, testing hypotheses, evaluating evidence, and revising hypotheses (Kuhn, Amsel, & O'Loughlin, 1988; Klahr & Dunbar, 1988; Klahr, 2000; Germann *et al.*, 1996b).

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Because the central task of science is to explain natural phenomena in terms of cause-effect relationships, scientific reasoning involves generating and testing causal hypotheses. Scientists construct and revise models as new evidence is generated (Kuhn, 1989). Furthermore, science involves the formulation of hypotheses or theories to describe and explain the observed facts. The focus of science is formulating a hypothesis and testing the hypothesis. The ability to evaluate claims or theories and their relation to the evidence is an important skill (Ruffman et al., 1993), and the ability to test hypotheses has been postulated to play a central role in a variety of cognitive processes (e.g., Moshman, 1979).

The term "hypothesis generation" may be defined as the process of creating possible alternative explanations for a given set of information or data. It logically involves retrieving potential hypotheses from semantic memory. Investigations of memory retrieval processes in hypothesis generation are important because several data are typically available for retrieval cues (Fisher *et al.*, 1983). The retrieval process is responsible for converting potential hypotheses stored in memory from an inactive state to an active one. The plausibility assessment process is used to evaluate or test active hypotheses in terms of their suitability in accounting for the available data (Mehle *et al.*, 1981). The retrieval and plausibility assessment processes and an additional executive process constitute the overall hypothesis generation model. In general, scientific inferences are based on the principle of eliminating hypotheses while provisionally accepting only those that remain (Wason, 1960, 1968).

Because prior knowledge plays a role in determining the plausibility of alternative hypotheses, the experimental strategy is used to test a hypothesis (Klahr *et al.*, 1993) and to retrieve the hypothesis. What an individual already knows (prior knowledge) exerts a powerful influence on what he or she will come to know (Alexander *et al.*, 1994; Dochy, 1992). If prior hypotheses are inconsistent with the evidence being generated, evidence may be overlooked or incorrectly interpreted. On the other hand, if the hypotheses are consistent, they may facilitate appropriate interpretation of the evidence (Kuhn *et al.*, 1988). When students are revising their hypotheses, they are likely to vacillate from evoking their existing knowledge to restructuring it (Schauble, 1990). Kuhn (1989) suggests that children may have problems differentiating and coordinating their evolving theories and the relevant evidence.

Classroom studies of scientific reasoning in science education have centered on the basic and integrated science process skills as key elements in inquiry. Most researchers would consider the development in adolescence of processes such as observing, classifying, formulating hypotheses, controlling variables, experimenting, interpreting data, and drawing conclusions as essential for inquiry. Sodian, Zaitchik, and Carey (1991) showed that a majority of their first graders and almost all of the second graders could differentiate hypothetical beliefs from evidence. Cortez and Niaz (1999) showed that even 11th grade students have considerable difficulty in differentiating among observations, predictions, and hypotheses. Kuhn and her colleagues (Kuhn, 1989; Kuhn *et al.*, 1988, Kuhn & Phelps, 1982) have argued that young children and many adults find it difficult to make a distinction between theory and evidence and between testing hypotheses and producing results. Ruffman *et al.* (1993) suggested that young children may overly depend on other sources of information, such as prior beliefs.

The investigation of hypothesis testing has been concerned with both descriptive and prescriptive issues. Researchers have been interested in understanding the processes of form, test, and revising hypotheses in an inquiry (Klayman & Ha, 1987). Moreover, students tend to focus on a single hypothesis and attempt to gather supporting evidence by repeating a single value of a single variable in a variety of contexts (Tschirgi, 1980). The hold-one-thing-at-a-time strategy entails the possibility of gaining no new information from any test, and it never allows the elimination of co-occurring alternatives. The vary-one-thing-at-a-time strategy will always allow tentative confirmation or absolute dis-confirmation of some variable on any one test.

Many students prefer the engineering method over the scientific method (Schauble *et al.*, 1991). The main objective of engineering practice is to optimize a desired outcome, and much of engineering experimentation is organized around this objective. In contrast, the science model as pursued in science education is the identification of causal relations between variables and outcomes.

Cognitive psychologists typically approach the problem with controlled laboratory studies while science educators are concerned with studying the problem in a classroom environment. The result of a controlled situation in a science laboratory would express different results. Few research studies actually use practical examinations to assess student achievement of the science process (Hofstein & Lunetta, 1982). These studies (eg., Wason, 1960; van Joolingen & Jong, 1991; Klahr & Dunbar, 1988; Schauble, 1990) have used relatively limited and arbitrary laboratory simulations of real-world events. Therefore, the participants could not assume that their real-world knowledge would be represented in the regularities they were attempting to discover. Common to all of them is the process of experimentation, which includes forming hypotheses, making and testing predictions, and modifying the hypotheses.

A greater part of formulating hypotheses is the rule discovery (Adsit & London, 1997; Klayman & Ha, 1987). For example, Wason (1960) and Klahr and his colleague used simple simulation of real-life situations in which the subjects should discover the rule by which the simulation doll or car moves. Prior researches about hypotheses focus on how to analyze the quality of the hypothesis in science education. Germann *et al.* (1996a) analyzed the qualities of asking the question, identifying the variables, identifying the experimental control, and formulating the hypothesis. Quinn & George (1974) argued about the quality of the hypothesis. Kwon *et al.* (2003) and Park (2000) suggested a procedure for formulating hypotheses according to explanation hypotheses and theory hypotheses. Yang *et al.* (2003) explored the students difficulty and the reasons for such difficulty in scientific discovery. They also studied what could be the cognitive source of this difficulty.

Scientists do not formulate a hypothesis just once and then test all formulated hypotheses in science works. Germann *et al.* (1996b), Quinn & George (1974), and Kwon *et al.* (2003), analyzed the formulation of hypotheses and the designing of an experiment. However, these researches were proven to be insufficient that the understanding that changes may occur after the accepted or rejected hypothesis. Therefore, this research analyzes the formulation and revision of hypotheses through repetition hypothesis activities.

This research analyzes the students' processes of making and revising hypotheses. The specific research problems are: Are there quantitative and qualitative changes between the first hypothesis and second hypothesis? Do students reject or accept a hypothesis based on the results of the experiment? Do students use the results of the experiment in formulating the hypothesis?

## Theoretical background

The investigation of hypothesis testing has been concerned with both descriptive and prescriptive issues. Researchers have been interested in understanding the processes of form, test, and revise hypotheses in scientific investigation (Klayman & Ha, 1987). Sodian *et al.* (1991) showed that a majority of their first graders and almost all of the second graders could differentiate hypothetical beliefs from evidence. Cortez & Niaz (1999) showed that even 11th grade students have considerable difficulty in differentiating among observations, predictions, and hypotheses. Kuhn and her colleagues (Kuhn, 1989; Kuhn *et al.*, 1988, Kuhn & Phelps, 1982) have argued that young children and many adults find it difficult to make a distinction between theory and evidence and between testing hypotheses and producing results. Ruffman *et al.* (1993) suggested that young children may overly depend on other sources of information, such as prior beliefs and knowledge.

Klahr (2000) suggest dural space as a hypothesis space and experimental space and interaction with each others. These space are sufficiently different that they require different representations, different operators for moving about in the space, and different criteria for what constitutes progress in the space. It is clear that the problems to be solved in each space are different, even though they have obvious and necessary mutual influence. Search in the hypothesis space is guided both by prior knowledge and by experimental results. Search in the experiment space may be guided by the current hypothesis, and it may be used to generate information to formulate hypotheses (Klahr, 2000).

Moshman & Thompson (1981) suggest that conceptualize the development of hypothesis-testing competencies in terms of six discrete sequences, involving a) interpretation of the hypothesis; b) the distinction between using theories and testing theories; c) the consideration of multiple possibilities; d) the relation of theory and data: e) the nature of vertification and falsification; and f) the relation of truth and falsity. Although these sequence are consistent with available evidence, they should considered theoretical, and in some respects perhaps even speculative.

Elementary school children are generally considered to lack an understanding of the scientific method. That is, while young children may construct intuitive theories of the world, they lack metaconceptual awareness of this fact and have little understanding of the components of scientific reasoning. (eg Dunbar & Klahr, 1989; Kuhn, 1989). asked to determine the causes of a particular phenomenon, they often fail to test hypotheses in a systematic way: instead, they act as if their goal were simply to produce or repeat the effect, rather than to discover its causes. when evaluating hypotheses concerning the effects of particular variables, they often fail to control for confounding variables. when interpreting the results of their experiments, they usually account for only parts of the available data, neglecting evidence that conflicts with their currently favored interpretation. They hardly ever explicitly seek such discinfirming evidence(Sodian *et al.*, 1991).

The development of scientific reasoning skill encompasses two types of knowledge: a) domain-specific knowledge about the natural world, and b) domain-general procedures for generating, assessing, and integrating that knowledge. The former includes substantive knowledge about particular domains and the latter includes a complex set of cognitive skills used to support scientific discovery, including the search for hypotheses via induction, abduction, or analogy: the design, execution, and interpretation of experiments: and the revision of hypotheses (Penner & Klahr, 1996).

# Ⅱ. Methods

## Programs

The programs for repetition hypothesis activities that drew a formulating hypothesis and designing experiment. This program does not treat in current elementary and secondary science curriculum in Korea. The content of the program is frozen goldfish, candle combustion, heart beat, digestive enzymes, and enzyme. Observing, posing question, formulating initial hypothesis, designing experiment, analysing results, formulating secondary hypothesis, designing experiment, analysing results, and drawing conclusion recorded in order at the worksheet. Fig 1. show flowchart of the programs. Detail content is as follows;

① Observing; We show the curiosity to students the phenomenon to raise, and then record everything students observe while doing the experiment. Do the experiment several times to observe the result carefully.

② Posing questions; Record as many question that student would like to know about their observations. When specific question is not produced or there is the difficulty in a question formation, the teacher gives the aid. We make common question through a classroom discussion

③ Formulating initial hypothesis: Make as many alternative explanations (hypotheses) as students can for all the observations and posing questions

④ Designing experiments; Select one hypothesis among their hypotheses. Then, design an experiment for testing their chosen hypothesis. Describe designing experiment in detail, step by step. When students designing experiment, the teacher guides for control variables. Also, when students designing experiment, predict the result to support the hypothesis

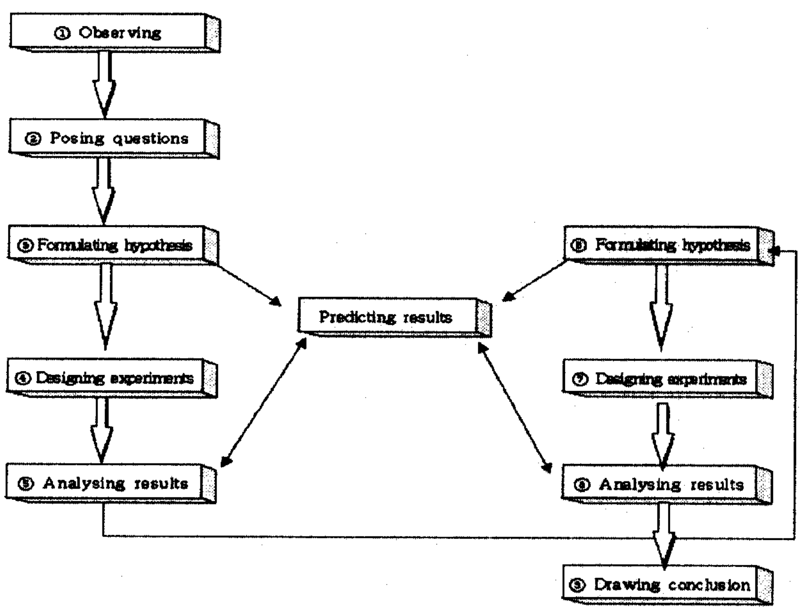


Fig. 1. Flowchart of repetition hypothesis activities

⑤ Analysing results; Whether or not rejected or accepted the hypothesis by the results of their experiment.

⑥ Formulating secondary hypothesis; If predicted result was different from actual results, the hypotheses is rejected. If hypothesis was rejected, students make a new hypothesis. When students make a new hypothesis, consider their results. Make as many hypotheses as possible and record them below

⑦ Designing experiments; Select one hypothesis among theri hypotheses. Then, design an experiment for testing their chosen hypothesis. Describe designing experiment in detail, step by step. When students designing experiment, the teacher guides for control variables. Also, when students designing experiment, predict the result to support the hypothesis

⑧ Analysing results; Whether or not rejected or accepted the hypothesis by the results of their experiment.

⑨ Drawing conclusion; Drawing conclusion through the experiment.

## Sampling

Subjects were 16 7th grade students (9 boys, 7 girls) from middle school located in a city with 800,000 population. These subjects were student to have the interest in science as a science club.

## Data collection

The data for this research were collected through recorded at the worksheet about their experiments. The experiment experimented one subject at an one week and per an each experiment 2 class hour was given. The experiment began from September 2002 and during 5 weeks was processed. A science teacher of the school progressed the class. The teacher to guide the class has 10 years of service. She is a doctor course student about the research who studies in the inquiry in the laboratory and learning cycle. She has research experience for formulating hypothesis, executed an alternate experiment.

## Data analysis

The method of the Germann *et al.* (1996a) was used to find whether the quality of the hypotheses was analyzed by testing hypotheses that were selected among the many hypotheses formulated by students. The quality of the hypotheses was analyzed by testing hypotheses that were selected among the many hypotheses formulated by students. Germann distinguished the level of formulating hypothesis to 7 steps; all essential and inessential elements present (A); all essential elements present (B); essential element ambiguous or too general (C); independent and dependent variables switched (D); essential element missing (E); question; constant; procedure; not relevant (F); and no response (G). The change in quantity of the hypotheses were analyzed in terms of the number of initial and secondary formulating hypotheses. Whether or not the hypotheses that should be rejected on the basis of compare predicted result with actual results of the experiment was analyzed. We analyzed whether students used the result of the first experiment to get when they formulated a second hypothesis.

# Ⅲ. Results

The objective of this study is to formulate a hypothesis on the questions about the observed facts after observing scientific phenomena. Treatment programs were consist that the experiment is conducted, the results are analyzed, and then the hypothesis is reformulated. The results of this study was based on the analysis of whether or not there was changes in the quantity and quality of the hypotheses before and after the experiment and whether or not the hypotheses that should be rejected on the basis of the results of the experiment was indeed rejected.

### Changes in the quality and quantity of the hypotheses

To answer the questions on the observed facts, subjects tested the initially formulated hypotheses through experiment and conducted a second experiment with the reformulated hypothesis. The number of hypotheses refers to those formulated by individual student. Table 1 shows the number of initial and secondary hypotheses formulated by students. The Table suggests that there were fewer secondary hypotheses than initial hypotheses formulated.

**Table 1.** Change of number of formulating hypothesis

| Topic | No. of First hypotheses | No. of Second hypotheses |
|---|---|---|
| Goldfish | 38 | 26 |
| Candle combustion | 46 | 30 |
| Heart beat | 106 | - |
| Digestive enzymes | 66 | 27 |
| Enzyme | 40 | 24 |

In the experiment on 'frozen goldfish', there were 38 initial hypotheses and 26 secondary hypotheses; on 'candle combustion', 46 initial and 30 secondary; on 'digestive enzymes', 66 initial and 77 secondary; and on 'enzymes', 40 initial and 24 secondary. In the case of the 'heart beat' experiment, two experiments were conducted to test the initial hypotheses (which totaled 106, with one student suggesting 26) but secondary hypotheses were not formulated. The average number of formulating hypothesis were 3.7 initial hypothesis, 1.6 second hypothesis. The hypotheses formulated by students tended to be similar. For example, in the experiment on candle combustion, 10 out of 44 hypotheses stated that the more candle sticks there are, the more water comes up.

There were fewer secondary hypotheses than initial ones. However, the hypotheses that should be rejected with the results of the experiment were not rejected. The details of this will be analyzed specifically in the context of the rejection of hypotheses on the basis of the analysis and usage of the experiment results.

The changes in the quality of the hypotheses were investigated. The quality of the hypotheses was analyzed by testing, the hypotheses that were selected among the many hypotheses formulated by students. Therefore, the number of hypotheses analyzed, as shown in Table 2, thus became constant.

Most of the initial hypothesis in the 'frozen goldfish' experiment--i.e., hypotheses (F) which

**Table 2.** Change of quality of hypothesis ( ) : %

| | Goldfish | | Candle combustion | | Digestive enzymes | | Enzyme | |
|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| A. All essential and inessential elements present | - | - | - | - | - | - | - | - |
| B. All essential elements present | 4 (25.0) | 6 (37.5) | 8 (50.0) | 8 (50.0) | 15 | 7 (43.7) | 6 (37.5) | 9 (56.3) |
| C. Essential element ambiguous or too general | 4 (25.0) | 3 (18.7) | 2 (12.5) | 7 (43.7) | - | 4 (25.0) | 1 (6.3) | - |
| D. Independent and dependent variables switched | - | - | - | - | - | - | - | - |
| E. Essential element missing | - | 2 (12.5) | - | 1 (6.3) | - | - | - | - |
| F. Question; constant; procedure; not relevant | 7 (43.7) | 3 (18.7) | 6 (37.5) | - | - | 5 (31.3) | 9 (56.3) | 7 (43.7) |
| G. No response | 1 (6.3) | 2 (12.5) | - | - | - | - | - | - |

question; constant; procedure; not relevant (7), whereas most of the secondary hypotheses not relevant question; constant; procedure (6). In the experiment on 'candle combustion', there were 6 hypotheses on (F), and no such secondary hypotheses; and there were 8 initial and 8 secondary hypotheses on all essential elements present (B). In the experiment on the 'enzymes', there were 9 items F in the initial hypotheses but this went down to 7 in the secondary hypotheses, and there were 6 items B in the initial hypotheses which became 9 in the secondary hypotheses. In the experiment on 'digestive enzymes', there were 15 items B in the initial hypotheses but only 7 in the secondary hypotheses, in addition to 4 items C and 5 items F.

The quality of students hypotheses increased with their secondary hypotheses from their first hypotheses, and yet decreased with their secondary hypotheses. This is attributed to the degree of preliminary experience of students in the task to be performed. The experiment on 'digestive enzymes' was not conducted in elementary school but students are assumed to be familiar with the topic compared to other topics due to lessons on nutrients in elementary school. That is, this finding signifies the impact of students direct or indirect experiences on the quality of their hypotheses(Ruffman *et al.*, 1993; Alexander *et al.*, 1994). Also, this is due to students lack of recognition of the strategies in formulating hypotheses (Sodian, *et al.*, 1991). Students had insufficient recognition of the relationships among the initially formulated hypotheses, and when the hypotheses they formulated and selected were accepted, they rejected most of the existing hypotheses(Kuhn *et al.*, 1988). After considering the objectives, the initial hypotheses and the findings of the experiment, students should have formulated their hypotheses. The quality of their hypotheses was low, however, since they formulated them by intuition. Most of students expressed the relationships among the factors in the hypotheses, but there were students who could not do so. For example, students who formulated a hypothesis on the observed contents expressed it as a question and the title of the experiment. Students expressed the hypotheses as follows:

- Defrosting goldfish quickly;
- Save goldfish;
- Conduct the experiment with more candles; and
- Infuse gas.

These kinds of hypotheses appeared in the initial and secondary experiments but not in the rear experiment. Due to students lack of training in formulating and defining hypotheses, it is assumed that they could not express the hypotheses as relationships among the factors but only as questions and the title of the experiment. In addition, the contents of the experiment were expressed in students current textbook as a question or the title of the experiment. Accordingly, instruction on the systematic formulation of important hypotheses should be given in the process of scientific exploration and advanced thinking.

**Rejection of hypotheses**

To test a hypothesis, an investigation was conducted on whether or not the initially formulated hypothesis was maintained or rejected on the basis of the results of the experiment. Several cases appeared. In the first case, the hypothesis should have been rejected on the basis of the results of the experiment, but could not be. Most of students experienced this case. The following is an example of such, involving student A, on the experiment on 'digestive enzymes';

- Initial hypothesis: Carbohydrates and fats will be digested.
- Result: Carbohydrates and fats were mostly digested but protein was not be sufficiently digested.

To support student as hypothesis, the digestive pill should digest carbohydrates and fats, but not protein. In the experiment, however, carbohydrates, fats and protein were all digested. The hypothesis should thus be rejected based on the results of student. As experiment, but it was instead accepted. More importantly, the student formulated this hypothesis to support the results of the experiment that carbohydrates, fats and protein will be digested. The following is an example of student Bs case;

- Initial hypotheses: Carbohydrates, fats and protein will be digested.
  Carbohydrates and fats will be digested.
  Carbohydrates will be digested.
- Selected hypothesis: Carbohydrates, fats and protein will be digested.
- Result of the experiment: Carbohydrates were digested.
- Secondary hypothesis: If two digestive pills are mixed, their degree of digestion will increase.

As with student A, the hypothesis formulated by student B should be rejected his selected hypothesis and student B should conduct the experiment again with another hypothesis among those in the list of initial hypotheses. Since the expected partial results of the experiment agreed with the actual results, however, the student concluded that the hypothesis was supported. Although students should conduct the experiment again with a new hypothesis after rejecting the hypothesis selected, they could not do so, basically because of their lack of training in evaluating the hypothesis on the basis of their proofs. This is possibly because in reality, experiments in Koreas science laboratory are conducted with an emphasis on the results suitable for theory, instead of the initial thought being modified on the basis of the results of an experiment. At present, laboratory education puts priority on judgment based on proof (NRC, 2000), but there is a lack of interest in this matter in Korea.

Another reason why students could not conduct another experiment with a new hypothesis after the hypotheses they first selected is rejected is that students do not have the ability to distinguish what they believe from the proofs that either support their belief or not (Sodian, *et al.*, 1991). When contradictory proofs appeared, they slanted them so as to make them suit their belief or paid attention only to the proofs that supported their belief (Ruffman, *et al.*, 1993). Moreover, when an evaluation of the proofs (or the results of the experiment) was requested from students, they persisted with the theory (or belief/hypothesis) that they have acquired in advance, ignoring the proofs.

Secondly, to rationalize or test their hypothesis, students looked for a new experimental method. In this case, after their hypothesis was proven wrong in the experiment, they tried to prove it using other methods instead of rejecting it. Following is a record of a hypothesis by student C, the expected results and the actual results;

- Initial hypothesis: Digestive pills can digest carbohydrates.

| Expected result | Actual result |
|---|---|
| There will be no change in the test tube containing the starch solution. | As expected, there was no change in the starch solution nor in the fat solution. |

For student Cs above hypothesis to be supported, there should have been no change in the starch solution but there should have been changes in other test tubes. He rejected the hypothesis on the basis of the results of student Bs experiment. To test the hypothesis that digestive pills could digest carbohydrates, however, another experiment was conducted. Other digestive pills were used to conduct the experiment differently. Student C rejected the hypothesis on the basis of the results of the experiment, which were different from those in the first experiment, but which tended to prove that the hypothesis formulated was right without modification. This proves that students had a strong belief in the hypothesis selected (Robinson & Hastie, 1985).

The results partly supported students hypothesis and showed their tendency to believe even more in the hypothesis they formulated. According to an advanced study (Teigen, 1983), students use another method to prove the hypothesis they selected or to prove a theorythat is, by being extremely obsessed with the part of the proofs that support the reagents hypothesis.

In the third case, when the expected results agreed with the actual results, the hypothesis was supported. Student D conducted an experiment on the 'enzymes', with the hypothesis that the molecules in potatoes react with hydrogen peroxide to produce bubbles. He put hydrogen peroxide in a test tube and a potato to test his hypothesis and insisted that his hypothesis was supported because bubbles were formed as he had predicted. He did not recognize that he was not able to control the factors.

In the fourth case, when a selected hypothesis was supported, all other formulated hypotheses were rejected and a new hypothesis was made. In this case, several hypotheses were formulated before one was selected. If the selected hypothesis was proven in the experiment, all the other formulated hypotheses were discarded and a new one was made for the second experiment. In the experiment on candle combustion, for instance, student D could be observed as an example.

- Initial hypothesis: Conduct the experiment with various quantities of candles.
  Increase or decrease the height of the candles.
  Increase or decrease the amount of water and conduct the experiment.
  Change the size of the bottles and conduct the experiment.
- Experimental hypothesis: Increase the number of candles and conduct the experiment.

| Expected result | Actual result |
| --- | --- |
| As the number of candles increases, the amount of water going up will also increase. | Each time a candle was installed, the amount of water going up increased by 1.5 times or double. |

- Second hypothesis: As the number and height of candles increase, the amount of water going up will also increase.

Although student D expressed his experimental hypothesis ambiguously, his hypothesis was supported. In his second formulating of hypotheses, #3 and #4, which were not tested, were discarded but a new hypothesis was formulated by integrating #1 and #2. Some of students in this case conducted the experiment to confirm their selected hypotheses.

In the fifth case, when students selected hypothesis was supported, all initially formulated hypotheses were rejected and a new hypothesis was selected. To answer the questions on the observed facts, if one of the many initially selected hypotheses was selected while the experiment was being conducted and if this hypothesis was supported, students should select another hypothesis among those formulated and then conduct the experiment. If the test results supported the hypothesis, however, all initially formulated hypotheses should be rejected and new ones should be made. Student Es case is given as an example below.

- Initial hypothesis: The bigger the glass bottle is, the more water will go up.
  The longer the candle wick is, the more water will go up.
  The more candles there are, the more water will go up.
  The more oxygen there is, the more water will go up.
- Selected hypothesis: The more candles there are, the more water will go up.
- Second hypothesis: The thicker and bigger the bottle is, the more water will go up.
  The more carbon dioxide there is, the less water will go up.

In the case of student E, if his hypothesis was supported in the experiment in terms of the relationship between the number of candles and the amount of water going up, he should have changed the size of the glass bottle, the length of the candle wick, and the amount of oxygen in the next experiment and then conduct the experiment. Student E rejected the rest of the hypotheses that were not selected, however, since his selected hypothesis was supported. The second hypothesis, moreover, was based on the thickness and size of the bottles and the amount of carbon dioxide, which did not appear in the initial hypothesis.

## Usage of the results of the experiment

The findings from the experiment should be used to formulate a new hypothesis. In the first place, they can be assumed to be a kind of knowledge that students themselves obtained. In this study, whether or not the obtained knowledge via experimentation should be used to formulate a hypothesis was investigated. The results of the experiment were classified into two cases--the case supporting the hypothesis and that not supporting the hypothesis.

The first case involves obtaining the results of the experiment in which the hypothesis is supported. In such a case, the initially formulated hypotheses should be rejected and the selected hypothesis should be accepted. Moreover, both the hypotheses that were not tested in the experiment and the newly formulated hypotheses should be further tested. When the experiment supported students hypothesis, however, they rejected all the other hypothesis and formulated a completely new hypothesis. This is the case of student E, who was observed in the analysis of the rejection of the hypothesis. Students rejection of their other initial hypotheses could be attributed to their inability to understand the relationships among the hypotheses they formulated, the relationships between the results of the experiment and their hypotheses, and the meaning of the results of the experiment. It is when the test results came out that the second hypothesis should have been rejected.

The second case when only part of the results of the experiment supports the hypothesis (in which case the hypothesis should be rejected) and when the results of the experiment do not support the hypothesis at all. When the part of test results supported students hypothesis, students judged that their hypothesis was supported. The cases of students B and C correspond to the case shown in the above examples. When the results of the experiment did not support their hypothesis at all, students concluded that the method they used for the experiment was not right and they changed it to continuously try to prove their hypothesis. This is the case of student D.

As with students A and B on the matter of the rejection of their hypothesis, the results of the experiment could not be used in the next experiment since the hypothesis was not selected in the experiment. Although the hypotheses they formulated existed, they did not change it into that hypothesis since they could not desist from their belief in their selected hypothesis.

There are several reasons for this behavior. First, it can be assumed that the process of experimentation did not change students belief, which emanated from their prior knowledge. As Klahr suggested SDDS, the results of searching in the space of experimentation can impact on the searching of hypothetical space, and yet the young students are assumed not to have that competency. Another assumption is that the results of the experiment on selected hypotheses are not provided in the alternative hypotheses, as Robinson & Hastie (1985) suggested. In relation to super-recognizing perception, it is judged that students could not internalize the experimental experience or lack the competence of internalization.

## Discussion and suggestions

After formulating hypotheses twice, their quality and quantity, their rejection, and their usage in scientific investigation activities of 7th grade students were investigated. Students could not clearly see the relationship between their hypothesis on natural phenomena and the proofs obtained (Germann, *et al.*, 1996a). Moreover, they could not use the results of the experiment to modify the proofs. This can be attributed to students lack of super-recognition activities (Kuhn, 1989; Sodian, *et al.*, 1991), because of which the problem-solving process could not be actively established. Klahr & Dunbar suggested that the problem-solving process in science be carried out through the interaction of hypothetical space and experimental space. Unlike with scientists, students did not actively carry out this process.

Based on experimental proof, scientists modify their beliefs and hypotheses. They utilize various competencies in regulating theory and proofs. For example, they should be equipped with the theory to think about natural phenomena and to acquire them. Theory and proofs are mutually distinctive and proofs seem to be used to evaluate theories whereas the rejection and acceptance of theories consider the proofs. Students could not distinguish, however, the proofs from their theories. They should reject their theories, beliefs and hypotheses on the basis of proofs but they maintained them continuously. Moreover, to prove their hypotheses, they modified their method of experimentation. They also conducted more experiments on the basis of the scientific experimentation model instead of the engineering experimentation model (schauble *et al.*, 1991).

Students were only interested in the results that supported their hypotheses and could not observe the causal relationships among all the factors. When the results of their experiment matched their expected results, they concluded that their hypothesis was supported. When the results supported only part of their hypothesis, however, they paid attention only to the part of the results that supported their hypothesis and concluded that their hypothesis was supported. Their evaluation of the results impact on solving problems, especially on selecting the test to produce the proofs. In the case of adults and children, considering the results of the practical issues, they use sensible strategies in relation to the task. These strategies are not always logical, however, in the sense of formula, because in the case of students, they preferred to uphold the one-thing-at-a-time strategy in the process of modifying their hypothesis on the basis of the results of the experiments. That is, they focused on one hypothesis and collected proofs supporting that hypothesis (Tschirgi, 1980).

According to Klahr and his associates, the acquisition of knowledge and scientific discoveries comes from the interaction of knowledge and the process of interaction of hypothetical space and experimental space. In the case of scientists, this interaction is actively made, but students could not make the interaction actively. Moreover, in the search for the two spaces, it is not clear from this study whether or not students used the strategies of experimenters or of theoreticians in conducting their experiment in a laboratory situation. Additional researches on this matter are expected to be conducted.

From these analyses, several suggestions are made on how to improve science education in Korea. First, when conducting experiments in a laboratory, students should establish their hypothesis and evaluate its quality. They should express this hypothesis as the temporary relationship among the factors involved instead of as a question or the title of the experiment.

Laboratory experiments in Korea mainly confirm scientific concepts, which do not improve students scientific thinking abilities. In addition, after analyzing the questions on the evaluation of the level of scientific thinking of students and that reflected in their science textbooks and their schools, the level of thinking in their textbooks and in the items on the evaluation of the 7th grade students is lower than that of middle school students (Kim, *et al.*, 2003). This signifies the need to train students on formulating hypotheses, which is required in advanced thinking.

Second, experiments emphasizing the evaluation of proofs should be conducted not only in the field of science but also in other subjects, since these will develop students super-recognition competencies. In science subjects, moreover, super-recognition is highlighted in the acquisition of science concepts. This study and advanced studies emphasize the role of super-recognition in the process of establishing hypotheses. Accordingly, to improve students super-recognition competence, proofs that are collected to test a hypothesis should be evaluated and training on the rejection and acceptance of hypotheses should be carried out.

Third, laboratory instruction should be carried out based on the scientific experimentation model. Current laboratory experiments focus on experiments that produce the expected results, and the results of experiments are used to confirm scientific theories suggested in textbooks. Students modify the method of experimentation to draw the expected results rather than change their hypothesis based on the results of their experiments. Instead of conducting the experiments so as to examine the relationships among the factors, they rejected all other hypotheses after judging that all their selected hypotheses were supported.

As an experimental model, the scientific model establishes the temporary causal relationships among important factors and emphasizes the removal of, the reasoning behind, and the deduction of uncertainty. Tests are conducted for all possible combinations and after a systematic search is completed for all factors, the experiment is completed.

Fourth, inquiries or integrated researches on complicated subjects should be conducted. Science laboratories focus on simple activities such as observation, measurement and classification. Although these activities are important in scientific investigation, these cannot improve students scientific reasoning. Since these activities require a level of thinking that is lower than that of students, they cannot arouse students interest.

To improve students thinking ability and arouse their interest, activities with various complex investigative elements should be conducted rather than just questions on simple or complicated investigations. By answering complicated questions, students will have opportunities to use advanced thinking such as super-recognition, deduction, induction and reasoning.

## Ⅳ. Conclusion

This study investigated changes in the quality and quantity of hypotheses, the rejection of hypotheses, and the usage of the results of experiments by establishing hypothesis repetitively through 5 scientific investigation activities. The subjects of this study were 16 middle-school students in their 1st year. With repeated formulation of hypotheses, their quantity decreased and their quality increased. Their rejection was not based on the results of their experiments, students maintained their beliefs, and they did not use the results of the experiments to establish a new hypothesis. The conclusions drawn from the results of the experiments follow.

The proofs obtained from the experiments did not play a key role in determining the rejection or acceptance of the hypotheses. Instead, students stuck to their belief of, and expectations from, the hypotheses that they established, and in analyzing the results of the experiments, they focused on obtaining their expected results to support their selected experimental hypothesis. This is because they lacked the ability of super-recognition in the process of establishing their hypothesis (Sodian, *et al.*, 1991). Because students had insufficient recognition of the relationships among their initially formulated hypotheses, when these hypotheses that they formulated and selected were proven, they rejected all other previous hypotheses. When they are revising their hypothesis, students are likely to vacillate between evoking their existing knowledge to restructuring it. Moreover, students conducted the experiments using the engineering model rather than the scientific model.

They lack a synthesis of the literature relevant to the interaction of domain-specific and strategic knowledge. The internalized knowledge obtained from the experiment was not used to establish a new hypothesis, to design the experimentation process and to interpret the results. If the results of the experiments are not internalized, the period of their internalization becomes longer.

The hypothetical space was not the fixed one. Although the 7th grade students did not produce enough interaction between the hypothetical space and the experimental space, the hypothetical space was changed by the changes in the experiment results and in students beliefs. As students showed, the selected hypotheses were proven by experimentation and the hypotheses to be rejected from the results of the experiments were rejected.

An additional investigation should be conducted on why the initial hypothesis was rejected, as proof of the soundness of the selected hypothesis. Even so, the hypothetical space showed a dynamic form. The quality of the hypothesis was low. In the study of students in the science class, the level of their hypothesis was not sufficient. The explanations on the relationships among the factors in the process of establishing the hypothesis were not sufficient, as were students suggestions on the titles of the experiments, the questions, and the hypotheses. Students could not conduct a truly scientific investigation. Students should select many factors related to solving the problems and figure out the relationships among the factors. They did not conduct the experiments in this manner, however, but instead focused only on the factors .

Moreover, had the results supporting the selected hypothesis not come out, students would have adjudged the experiment erroneous, and they showed an extreme tendency to interpret the results of the experiment in a manner that supported their selected hypothesis.

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