Jour. Korean Earth Science Society, v. 32, no. 2, p. 225–238, April 2011
doi : 10.5467/JKESS.2011.32.2.225

Exploring Students' Ability of 'Doing' Scientific Inquiry: The Case of Gifted Students in Science

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과학탐구의 '실행' 능력 탐색하기: 과학영재학생 사례 중심으로

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Abstract: The purpose of this study was to explore the factors that are critical for successful scientific inquiry activity in the classroom and to analyze the students' abilities of 'Doing' scientific inquiry. Two hundred and forty gifted science students in grades 7th and 8th participated in this study and demonstrated their abilities of framing questions and designing investigation through a survey questionnaire. The survey was developed for measuring factors in terms of personal and interactive variables that are needed for 'Doing' a successful scientific. Additionally, two other questionnaires were developed to measure students' abilities of framing testable questions and designing the investigation in a sequence. The results were as follows: Students' learning motivation factors as personal variable (self-confidence about group and inquiry activity, views about inquiry value) also considered as influential for students' group inquiry activity. Other four components of interactive variable (grouping, kinds of task, physical context, and teachers' role) were found to be influential in successful students' 'Doing' group inquiry activity. In students' evaluation of group inquiry activity, the grouping factor was the most critical one for a successful 'Doing' inquiry activity. Participating students showed some level of inability of in the process of framing inquiry question and designing investigation.

Keywords: scientific inquiry, personal factor, interactive factor, framing inquiry question, designing investigation

요 약: 이 연구는 교실상황에서 실현되는 성공적인 탐구활동을 위한 중요한 변수에는 무엇이 있으며 또한 학생들이 실시하는 과학탐구의 실행능력은 그 수준 정도가 어떻게 되는지를 조사하였다. 이 연구를 위해서 7학년 및 8학년의 과학영재학생들이 설문지를 작성하고 과학탐구의 실행능력 평가를 위해 탐구문제제기 및 탐구설계를 직접적으로 할 수 있도록 하였다. 설문지는 성공적인 과학탐구 활동에 영향을 주는 요소를 개인적 및 상호적 변수로 나눠 파악하였으며, 240명의 과학영재학생들이 설문에 응답하였다. 이 외에 두 개의 다른 질문지에는 탐구문제를 제기할 수 있는 능력과 탐구설계과정 능력을 측정할 수 있는 문항이 포함되어 있었다. 결과는 다음과 같다. 개인적 변수로는 그룹활동 및 탐구활동을 잘 할 수 있다는 확신과 과학탐구 가치를 높이 평가하고 있는 학습동기가 중요한 변수로 파악되었다. 또한 학생들의 성공적인 탐구활동에는 상호성 변수에는 그룹 편성, 과제종류, 물리적 환경, 그리고 교사의 역할이 중요한 성공 변수로 파악되었으며, 특히 그룹 편성은 학생들이 그룹탐구활동을 하는데 있어서 가장 중요하게 생각하는 변수로 파악되었다. 하지만 학생들의 탐구문제를 개발하는 능력이나 탐구설계를 하는 능력은 제한적으로 나타났다.

주요어: 과학탐구, 개인적 변수, 상호성 변수, 탐구문제제기, 탐구설계

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Introduction

Scientific inquiry in K-12 classrooms tends to be procedural, denying students the opportunity to understand how scientific knowledge is constructed through reflection, debate, and argument (Gallagher and Tobin, 1987). To promote scientific literacy, *Standards* (NRC, 1996, 2000) outline what students need to know, understand, and be able to do to be scientifically literate, based on an understanding of how scientists construct new knowledge through scientific inquiry. To meet this goal, students need to have chance to experience authentic scientific inquiry where they can understand how scientific knowledge is constructed through inquiry activity. Authentic scientific inquiry is what scientists do at their research site, whereas school scientific inquiry is what students do in their classroom (Bybee, 2000; Crawford, 2000; NRC, 1996, 2000; Park, 2006).

What is authentic scientific inquiry then? It is easy to spot activities inauthentic. Authentic scientific inquiry bears little relation to the cookbook lab activity found in science classroom (AAAS, 1993; Krajcik et al., 1998). Chinn and Malhotra (2002) defines that authentic scientific inquiry contains the process of reasoning. Authentic scientific inquiry involves designing complex procedures, controlling for non obvious confounds, planning multiple measures of multiple variables, using techniques to avoid perceptual and other biases, reasoning extensively about possible experimental error, and coordinating results from multiple studies that may be in conflict with each other. Schwartz and Crawford (2006) define that authentic scientific inquiry is what scientists experience in everyday practice, that is, what occurs within the scientific community by practicing scientists in efforts to gain understandings of the natural world. Here, negotiation is the critical process in authentic practice of science, involving argumentation. Kuhn (1986, 1993) also stated that students need to experience science as argumentation as well as science as exploration in order to understand the scientific thinking of scientists, which is objective of scientific inquiry in the classroom. Her concern is not that students acquire the correct experimentation strategies involved in traditional scientific hypothesis-testing, but that students develop the ability to coordinate their existing theories with new evidence they generate in an explicit and conscious way, which is similar to that of authentic scientific inquiry. The research about authentic scientific inquiry emphasizes students' opportunity of 'Doing' through argumentation as well as experimentation. Argumentation is important within in the social practice of science because students need to develop knowledge and understand the evaluative criteria used to establish scientific theories, which will enhance the public understanding of science and therefore improve scientific literacy. Therefore, group work is another critical component for effective scientific inquiry activity where argumentation can be rising (Erduran and Osborne, 2004; Jeong et al., 2008; Kim and Song, 2005; Park, 2008).

Scientific inquiry has two different dimensions; one is 'Doing' scientific inquiry and the other 'Understanding' about scientific inquiry (NRC, 2000). Table 1 includes summary statements of the abilities, 'Doing' and 'Understandings' for science as inquiry. 'Doing' is more focusing on 'Hands-on' and 'Minds-on' activity and 'Understanding' is more focusing on 'Hearts-on' activity (AAAS, 1989; Park, 2010; Park et al., 2010; NRC, 2000; Song and Cho, 2004)

Two abilities of 'Doing' and 'Understanding' for science as inquiry are related to the objectives of scientific literacy, where students have chances of developing scientific thinking skills as well as procedural skills through 'Doing' science as inquiry and experiencing the nature of science during 'Understandings' for science as inquiry. These two are critical components for students' experience of authentic scientific inquiry in the classroom. We can observe students' 'Doing' during inquiry activity. Students can frame questions, design investigation, carry out them, and make conclusions through the opportunity of procedural skills of 'Doing.' Students can also communicate with other peers and they can frame testable inquiry questions, use supportive evidences for their own theories, and refute the others with other evidences through the opportunity of scientific thinking skills of 'Doing.' Students can learn the nature of science

Table 1. Science as inquiry at Grade 5-8 (NRC, 2000)

Abilities Necessary to Do Scientific Inquiry	Understandings about Scientific Inquiry
-Identify questions that can be answered through scientific investigation	-Different kinds of questions suggest different kinds of scientific investigation
-Design and conduct a scientific investigation	-Current scientific knowledge and understanding guide scientific investigations
-Use appropriate tools and techniques to gather, analyze, and interpret data	-Mathematics is important in all aspects of scientific inquiry
-Develop descriptions, explanations, predications, and models using evidence	-Technology used to gather data enhances accuracy and allows scientists to analyze and quantify investigation results.
-Think critically and logically to make the relationships between evidence and explanations	-Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories
-Recognize and analyze alternative explanations and predictions	-Science advances through legitimate skepticism
-Communicate scientific procedure and explanations	-Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for investigation, or develop new techniques to improve the collection of data.
-Use mathematics in all aspects of scientific inquiry	

during their 'Doing' inquiry but which must be taught 'explicitly' not implicitly through the opportunity of 'Understanding' for science as inquiry (Khishfe and Abd-El-Khalick, 2002; Lederman, 1992). If we assume that these two opportunities of 'Doing' and 'Understanding' for science as inquiry are the critical factor for students to experience authentic scientific inquiry in the classroom, teachers' role of scaffolding through explicit teaching strategies are essential in that students must be provided opportunity to learn science as inquiry in terms of 'Doing' and 'Understanding'. 'Doing' and 'Understanding' are related to each other and they can occur at the same time, which means that students can experience 'Understanding' for science as inquiry by 'Doing' it. Students can understand the nature of science while they develop argumentation necessary when framing questions, designing investigation, collecting the data, and making conclusions. Therefore, it is basic to explore students' abilities of 'Doing' science as inquiry to develop concrete and explicit teaching strategies where students can be provided opportunities of 'Understandings' for science as inquiry. How can we know that students have real chances to 'Do' science as inquiry?

To explore the students' abilities of 'Doing' scientific inquiry, it is essential for teachers to provide them with opportunities of framing questions, making hypotheses, collecting and analyzing data, and concluding the remarks. In this study, first, I will explore how students can be provided opportunities to experience 'Hands-on' part of science as inquiry. Students will experience 'Minds-on' through argumentation and 'Hearts-on' through the nature of science, which both 'ON's can be possibly learnt by 'Hands-on' through experimentation (Park, 2010). In terms of 'Hands-on' in science as inquiry, students' abilities of framing questions and designing the investigation will be explored in this study.

This study has the following significance in science education. The exploration of students' abilities of 'Doing' science as inquiry emerged the limitation and lack of framing questions and designing the investigation during scientific inquiry, which, in turn, can be used as basic guideline in developing explicit teaching strategies and science inquiry standards. Teachers need to create authentic inquiry environment, where students have chances to frame testable questions, design the investigation, and carry out the experimentation. Before developing explicit teaching strategies and implementing authentic inquiry in the classroom, teachers are necessary to form and structure the firm knowledge about authentic scientific inquiry, all of which can be critical in teacher education, such as preparation program at university, induction and professional program for prospective, novice, and experienced teachers.

The purpose of this study is to explore what kinds of factors are critical for successful scientific inquiry activity in the classroom first, then explore and analyze students' abilities of 'Doing' scientific inquiry in terms of 'Hands-on'. 'Doing' scientific inquiry through 'Hands-on' is operationally defined with two components in this study. One is the ability of framing question and the other ability of designing investigation. My research questions are as follows; (1) what factors are critical for scientific inquiry? (2) Can students "Do" science as inquiry in abilities of framing questions and designing the investigation?

Methodology

Participants in this study

Gifted science students (grades 7^{th} and 8^{th}) participated in this study to respond surveys and to demonstrate their abilities of framing questions and designing investigation. Gifted students in this study had been familiar with scientific inquiry environment since they had been trained to explore different types of inquiry activity through gifted education program offered by universities or school district (Brophy, 1998; Chung and Park, 2010). The regular students at schools are not appropriate to be participants in this study, since they are not exposed to the context of authentic scientific inquiry environment during their school life. Therefore, gifted students are appropriate as participants to meet the purpose of this study. 240 science gifted students participated in responding survey for the first research question, releasing critical factors for scientific inquiry, and they framed inquiry questions and designed the investigation for the second research questions, measuring students' abilities of 'Doing' inquiry.

Research Context

32 different gifted education affiliations in Korea were contacted by the research team first for their permission of participating through consent form in this study. The survey, releasing critical factors for successful scientific inquiry implementation, was developed by the research team, distributed and 240 surveys were collected to be sent to the research team. Other two questionnaires were developed requiring students to demonstrate their abilities of framing testable questions and designing the investigation in a sequence. 240 set of questionnaires were also collected and then also delivered to the research team for data analysis.

Data Collection

The items of survey were developed by research team on the basis of theoretical underpinning about cooperative learning and scientific inquiry, since students' inquiry activity in small group is most critical context in 'Doing' inquiry activity. In Table 2, the survey consisted of independent variables of students' interactive and personal one, which in turn influence students' inquiry abilities of carrying out the investigation as dependent variable. The survey is Likert scale of 5.

First, independent variables are described as follows. Students' interactive variable again divide into four different factors; task (6 items), grouping (6 items), teachers' role (9 items), and physical context (5 items), all of which are considered as influential factors promoting students' interaction in 'Doing' scientific inquiry. Students' personal variable has two low rank factors; one is learning motivation and the other inquiry ability itself. Learning motivation factor again divides into three subdivisions; self-confidence about inquiry activity (10 items), self-confidence about group work (4 items) as well as points of view about inquiry value (6 items). About inquiry ability factor, students took tests to measure their abilities of how much they were qualified to frame testable inquiry questions and design the investigation, whose tools were employed from Jeong et al. (1995). The detail information in inquiry ability is provided in the following.

In framing questions, students are supposed to develop their own three different inquiry questions in terms of; (1) the content of question with precision, (2) its motivation to test those questions, (3) its hypothesis, that is, its prediction to the question and its reason why they predicted like that. In measuring student's abilities of designing investigation, participating students were

Table 2. The measurable factors for students' abilities of "Doing" scientific inquiry

Measurable factors				Number of items
Independent variable	Interactive variable	Task		6 items (interest, value, challenging, cooperation)
		Grouping		6 items (homo, heterogeneous, responsibility, personal roles)
		Teachers' role		9 items (objective, mentor, mediator, evaluator)
		Physical context		5 items (time, class period, lab materials, help from others)
	Personal variable	Learning motivation	Self-confidence about inquiry activity	10 items
			Self-confidence about group activity	4 items
			Points of view about inquiry value	6 items
		Inquiry ability	Abilities of framing questions	Jeong et al., 2004
			Abilities of designing investigation	
Dependent variable	Students' evaluation after group inquiry activity	Evaluation of inquiry activity		15 items (Eager and Yager, 2001)
		Evaluation of interaction		10 items (Johnson and Johnson, 2003)

required to design the investigation of "We can see the different colors of clouds from white to dark gray in the sky. Why is color so different like that?". Students are supposed to provide the detail procedures so that other people can carry out the experimentation; making hypothesis from question, preparing materials for experimentation, considering influential variables (independent, dependent, and controlled ones), instructing lab safety, and listing concrete procedures with the drawings if necessary.

Second, dependent variables are described as follows. Dependent variables consist of two categories; evaluation of inquiry activity and evaluation of interaction, measuring students' abilities of carrying out scientific inquiry in the context of small group. Those items were developed to evaluate the effectiveness of scientific inquiry activity in the context of small group. Those items were those asking students' evaluation of scientific inquiry activity itself and evaluation of students' interaction in small groups (Johnson and Johnson, 1989, 1994, 1997). Those two variables are considered as very critical ones in 'Doing' scientific inquiry. The items of scientific inquiry activity evaluate students' skills of scientific thinking as well as procedure after inquiry activity. The items of students' interaction in small group include students' evaluation of how they perform accountability, cooperation, opinion convergence from conflict such as.

Data Analysis

Statistical analysis was employed to describe how much each variable was contributing to students' abilities of 'Doing' scientific inquiry. The number of items from nine independent variables (interactive ones and personal one) and two dependent variables (evaluation of inquiry activity and evaluation of interaction in small group) were 71. However, inquiry ability variable from personal variable was excluded in the statistical analysis, since students' personal ability of framing question and designing investigation was more validated through descriptive analysis rather than statistical one in the given context of science content.

First, the average (out of 5) of each variable statistically was calculated indicating how much each factor was contributing to students' abilities of 'Doing' scientific inquiry. Second, the statistical correlation between dependent variables (evaluation of inquiry activity and interaction in small group) and independent variables (interactive ones and personal ones) were measured to find out the most critical variables influential to students' abilities of 'Doing' scientific inquiry. Third, to describe students' abilities of framing questions, the researchers (three science educators) developed the scoring guide with four different criteria and rubrics (Appendix 1). Four different criteria (its level, preciseness, motivation, and its hypothesis) were scored with maximum 3 points in each, whose full score was 12 in each question. Then the total of 3 developed inquiry questions was 36 for each student. Fourth, to measure 240 students' abilities of designing investigation, scoring guide with nine different criteria and rubrics (making hypothesis, selecting appropriate materials and equipment to test hypothesis, selecting appropriate variables, considering lab safety, controlling variables, planning observation and measurement, concluding remarks based on the collected data, completing investigation or repeating experimentation, and constructing the validity of inquiry procedure) were developed with maximum 3 points in each with the total score of 27 in each investigation (Appendix 2).

Results

Students' abilities of 'Doing' scientific inquiry

Factors contributing students' abilities of 'Doing' scientific inquiry: In components of interactive variables for group inquiry activity, the mean of kinds of task, grouping, teacher's role, and physical context were 3.78, 3.29, 3.48, and 3.18 out of 5 in order (Table 3), indicating that the characteristics of interaction in group for inquiry activity were in practice more or less.

The learning motivation is one of components in personal variable with the following subdivisions; self-confidence for inquiry activity, self-confidence for group activity, and points of view about inquiry value, whose means (out of 5) scored 3.66, 3.22, and 3.98 in order, indicating students participating in this study were pretty confident in 'Doing' group inquiry activity and hold high views about its value (Table 4).

Students also evaluated their own inquiry as well as group activity positively to some extent (Table 5). For example, the item of "I feel I can do better inquiry activity than others in my group", releasing students' self-confidence for inquiry activity, was rated high by

Table 3. The components of interaction variable

Interaction variable for group inquiry activity			
Component		Mean	SD
Interaction	Task (Ex) this task is very interesting theme.	3.78	0.47
	Grouping (Ex) our group is composed of intimates.	3.29	0.77
	Teachers' role (Ex) teacher motivates us to inquiry when introducing the task.	3.48	0.62
	Physical context (Ex) All materials are available in carrying out the task.	3.18	0.78

Table 4. The components of personal variable motivation

Personal variable for group inquiry activity			
Component		Mean	SD
Learning motivation	Self-confidence for inquiry activity (Ex) I like inquiry activity though the task is difficult.	3.66	0.66
	Self-confidence for group activity (Ex) I feel confident in getting along with any member in our group.	3.22	0.78
	Points of view about inquiry value (Ex) Inquiry task will promote my ability of developing creativity and logics.	3.98	0.68

Table 5. The components of evaluation for group inquiry activity

Evaluation for group inquiry activity			
	Component	Mean	SD
Group inquiry activity	Inquiry evaluation	3.43	0.56
	Group evaluation	3.44	0.70

students. The item of "I put high a valuation on inquiry activity as the solution for future problem" was also highly perceived by participants in the area of 'points of view about inquiry value'. Lastly, the item, for instance, "I can adjust myself to peer's opinions" was scored moderately, indicating that the factors of learning motivation were identified as the influential one for students' Doing inquiry activity.

In summary, students were pretty confident that they could 'Do' group inquiry activity 'well' and evaluated inquiry activity high enough as meaningful learning strategy in dimension of personal variable, and their interaction in 'Doing' inquiry activity seemed to be pretty promoted according to the kinds of given task, the way of grouping, teachers' role, and physical context in dimension of interactive variable. In addition, students participating in this study evaluated it positively that they are 'Doing' group inquiry activity. The correlation was analyzed to see how much four subdivision of interactive variable were related with students' evaluation of group, inquiry, and group inquiry activity in order.

As indicated in Table 6, students' inquiry activity evaluation correlated with kinds of task most ($r=.594$, $p<.01$), physical context ($r=.586$, $p<.01$), grouping ($r=.577$, $p<.01$), and teachers' role least ($r=.540$, $p<.01$), releasing that kinds of task given to students was very critical for them to do inquiry activity successfully. For example, the item in 'kinds of task given', "inquiry task is challenging enough for me to give a shot," was scored '5' by some participants. The item of 'physical context', "I could obtain all materials necessary for inquiry activity," was scored '5' by some participants, too. The item of 'grouping', "we need our own accountability for successful group activity," was scored '5'. Some students scored '5' in the item of 'teachers' role', "teachers evaluate our inquiry process often and provide appropriate direction." Students' group activity evaluation correlated with groping most ($r=.720$, $p<.01$), kinds of task ($r=.498$, $p<.01$), physical context ($r=.481$, $p<.01$), and teachers' role least ($r=.467$, $p<.01$), releasing they way of grouping students was the most critical for students to do group interaction successfully.

In summary, the way of grouping as the most, kinds of task given to students as the second, physical context as the third, and teachers' role as the least critical factor were considered for students' 'Doing' group inquiry activity successfully. It can be interpreted that science gifted students are familiar with 'Doing' group inquiry activity as the form of 'open' one rather than 'structured', resulting in students' preference to interacting with close and able partner in grouping without teachers' involvement.

Abilities of framing questions: 240 students developed their own three different inquiry questions with the following direction: (1) frame testable inquiry problem, (2) describe why you want to investigate this problem (related to motivation), and finally (3) describe what answers are expected to your question and why you predict like that way (hypothesis). Two inter-raters scored each student's inquiry problem to construct the validity of data analysis and they compared those

Table 6. The correlation between interaction variable and students' evaluation

	Interaction variables			
	Task	Grouping	Teacher's role	Physical context
Inquiry activity evaluation	**.594****	.577**	.540**	.586**
Group interaction evaluation	.498**	**.720****	.467**	.481**
Inquiry activity +Group evaluation	.596**	**.692****	.546**	.581**

** p<.01

analyses, discussed, and got to the final agreement with one science educator. Two scorers were trained by the researchers of this study at the beginning. Each inquiry question was scored with 4 dimension; testable content (3 points), its precision (3 points), motivation (3 points), and hypothesis (3 points), making 12 in total per problem. Each student had 36 points from three different inquiry problems. The means from three inquiry problems by all participants were 5.7, 5.0, and 4.4 each (total is 12 each), showing students' inability of framing inquiry question.

The 720 inquiry questions developed by 240 students were analyzed to see how much those questions are testable with the frame in Kim et al. (1998). Nine categories were developed to judge the possibility of testable inquiry questions with two dimensions of independent and dependent variables. Each variable was divided into three different types again; unclear, categorical, and continuous, making 9 different types of inquiry questions by two variables (Table 7). The example of categorical variable is different states of materials, such as gas, liquid, and solid. The example of continuous variable is one expressed by number, such as temperature, speed of sound, and so on. The example of each variable is provided in Table 8 with samples by students participating in this study.

The 720 inquiry questions by 240 students were divided into 9 different types of inquiry questions. Table 8 showed that 377 inquiry questions out of 720 (52.4%) were considered 'A' type with 'unclear' independent and dependent variables. 117 inquiry questions (16.3%) could not be judged as testable questions. The other types of inquiry questions by students participating in this study were considered as 'testable' inquiry questions. 554 out of 720 (68.7%) were resulted as 'NOT' testable questions to 'Do' inquiry activity (Table 9, Fig. 1).

Abilities of designing investigation: 240 students were given one inquiry problem and students were instructed to provide detail information so that other people can replicate the experimentation easily. The guideline which students were instructed to use is as follows (Table 10).

Two inter-raters scored each student's questionnaire of the designed investigation, using the scoring criteria developed by the researchers. The criteria has nine different sub-component with the maximum of 3 in each component, making the 27 in total (hypothesis, materials, variables, safety, description of controlling variables, providing concrete process of observation and measurement, proposing ideal interpretation based on the collected evidence, providing certain condition for terminating or repeating experiment, including the validity of experiment process). The means of students' abilities of designing the investigation was 14.8, which was pretty low compared to the total of 27. These results showed students' inabilities of designing investigation. Here is one example designing investigation by one student, displaying inability of making hypothesis, which

Table 7. Nine different types of inquiry questions (Gott and Duggan, 1995)

		Dependent variables		
		Unclear	Categorical	Continuous
Independent variables	Unclear	A	B	C
	Categorical	D	E	F
	Continuous	G	H	I

Table 8. Types of framing questions (Examples of each type)

Type	Example of inquiry questions by students in this study
A	Why is there a frame in foil in electronical range working?
B	What is the most influencing factor into hot weather of summer?
C	What influence to the magnitude of bulb light? What influences to the level of sweetness of fruit?
D	What would happen to the plant with coke instead of water?
E	What would happen to the plant with sprite?
F	What is the best way to throw the ball longest?
G	What would happen if the gravity would be gone on earth?
H	What is the best angle of knife to cut the fruit?
I	The change of power magnitude to the size of wing
J	*-Cannot judge at all as inquiry question-*

Table 9. Frequency of each type of inquiry questions by students in this study

Types	A	B	C	D	E	F	G	H	I	J	Total
Frequency	377	24	20	28	74	48	0	16	16	117	720
%	52.4	3.3	2.8	3.9	10.3	6.7	0	2.2	2.2	16.3	100

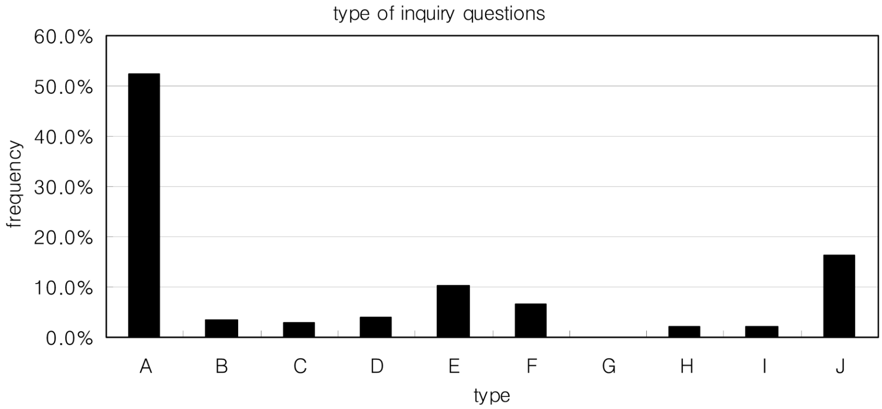


Fig. 1. Type of inquiry questions by students.

in turn influence another inability of selecting or controlling appropriate variables for investigation. In addition, students did not provide expected interpretation from concrete evidence with its validity, which resulted in low total score 14 points.

The results of this study can be summarized as follows.

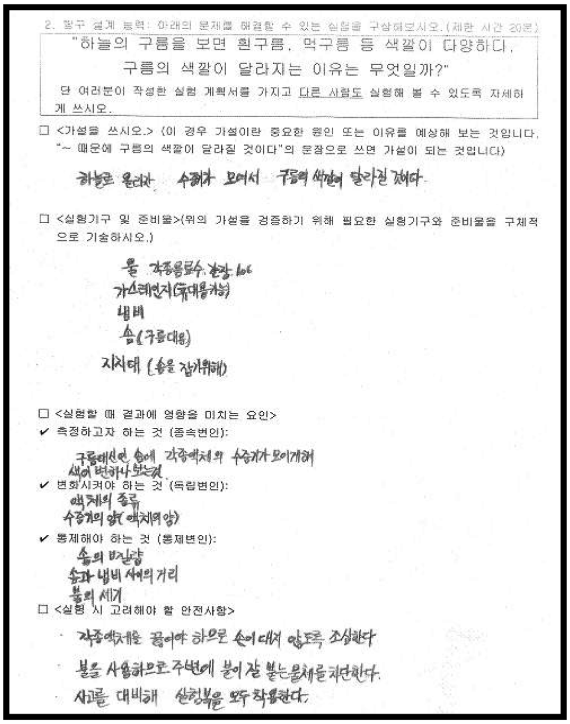
First, four factors of interactive variables (grouping, kinds of task, physical context, and teachers' role) were found to be influential in students' 'Doing' group inquiry activity through quantitative analysis. The grouping factor was the most critical one for students' evaluation of group inquiry activity by students. Students' learning motivation factors (self-confidence about group and inquiry activity, views about inquiry value) also considered as influential for students' group inquiry activity.

Second, students in this study displayed inability of framing inquiry question and designing investigation through qualitative analysis. Students developed three different inquiry questions and their scores were 5.7, 5.0, and 4.4 each (total is 12 each), indicating their inability of framing questions. In addition, 68.7% (554 out of 720) were considered as 'not' testable ones for investigation, indicating majority of students were not able to develop testable inquiry questions, which in turn influenced their another ability of designing investigation. The ability of designing investigation by 240 students scored 14.8 points out of 27, showing that students had difficulty in making hypothesis to be testable, selecting appropriate variables, interpreting with the evidence, and validating the experiments. Students who participated in this study demonstrated the inability of 'Doing' scientific inquiry in

Table 10. Guideline for designing investigation with the given inquiry question

Ability of designing investigation
Design the investigation testing the following inquiry problem: *"In the sky, you can see all different clouds in its shade; white, gray, or dark gray clouds. What do you think make this cloud so different in the shade like this?"* You design investigation to test this inquiry problem with steps following. (1) Hypothesis (You have to think of its reason why it happens. You can use "if, then" phrase) (2) Materials (to test the hypothesis) (3) Variables influencing the result of its experiment A. Dependent variable B. Independent variable C. Controlled variable (4) Safety for the lab activity (5) Procedures with the drawings if necessary. (6) Expected interpretation

Table 11. The example of designing investigation and its analysis



2. 탐구 설계 능력: 아래의 문제를 해결할 수 있는 실험을 구상해보시오.(제한 시간 20분)

"하늘의 구름을 보면 흰구름, 먹구름 등 색깔이 다양하다.
구름의 색깔이 달라지는 이유는 무엇일까?"

단 여러분이 작성한 실험 계획서를 가지고 다른 사람도 실험해 볼 수 있도록 자세하게 쓰시오.

□ <가설을 쓰시오.> (이 경우 가설이란 중요한 원인 또는 이유를 예상해 보는 것입니다. "~ 때문에 구름의 색깔이 달라질 것이다"의 문장으로 쓰면 가설이 되는 것입니다)

하늘로 올라간 수증기가 모여서 구름의 색깔이 달라질 것이다.

□ <실험기구 및 준비물>(위의 가설을 검증하기 위해 필요한 실험기구와 준비물을 구체적으로 기술하시오.)

물 각종음료수, 간장 etc
가스레인지(휴대용가능)
냄비
솜(구름대용)
지지대 (솜을 잡기위해)

□ <실험할 때 결과에 영향을 미치는 요인>

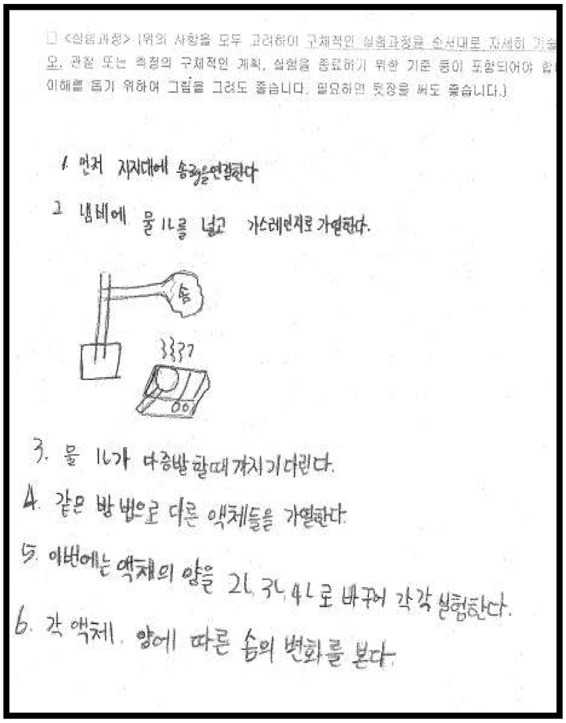
✔ 측정하고자 하는 것 (종속변인):
구름대신인 솜에 각종액체의 수증기가 모이게해 색이 변하나 보는것

✔ 변화시켜야 하는 것 (독립변인):
액체의 종류
수증기의 양(액체의양)

✔ 통제해야 하는 것 (통제변인):
솜의 양
솜과 냄비 사이의 거리
불의 세기

□ <실험 시 고려해야 할 안전사항>

· 각종액체를 끓여야 하므로 손이 데지 않도록 조심한다
· 불을 사용하므로 주변에 불이 잘 붙는물체를 치운다.
· 사고를 대비해 실험복을 모두 착용한다.



□ <실험과정> (위의 사항을 모두 고려하여 구체적인 실험과정을 순서대로 자세히 기술하시오. 관찰 또는 측정의 구체적인 계획, 실험을 종료하기 위한 기준 등이 포함되어야 합니다. 이해를 돕기 위하여 그림을 그려도 좋습니다. 필요하면 뒷장을 써도 좋습니다.)

1. 먼저 지지대에 솜을 연결한다
2. 냄비에 물 1L를 넣고 가스레인지로 가열한다.

3. 물 1L가 다 증발할때 까지 기다린다.
4. 같은 방법으로 다른 액체들을 가열한다
5. 이번에는 액체의 양을 2L, 3L, 4L로 바꾸어 각각 실험한다.
6. 각 액체, 양에 따른 솜의 변화를 본다

Hypothesis (The amount of water vapor makes colors in its shade of cloud: 1 pt), materials(water, soda, soy sauce, pot, cotton, holder, gas range; 2 pts), variables (the amount of water vapor as dependent variable, kinds of liquid as independent, the amount of cotton, the distance between cotton and pot, and the time period of frame as controlled variables; 2 pts), safety (safe from frame, lab gown with goggle; 2 pts), description of controlling variables (2 pts), providing concrete process of observation and measurement (2 pts), proposing ideal interpretation based on the collected evidence(0 pt), providing certain condition for terminating or repeating experiment (1 pt), including the validity of experiment process (1 pt).

terms of 'Hands-on'.

Conclusion

Learning motivation factor of personal variable and four factors (task type, grouping, teachers' role, and physical context) of interactive variable were found to be influential in successful students' 'Doing' inquiry activity. First of all, when the grouping factor is regarded as the most critical in students' 'Doing' group inquiry activity, teachers need to consider the way of grouping in their planning students' inquiry activity. Many researches (Johnson and Johnson, 1989, 1994, 1997; Marcy and Mumford, 2007; Palmer, 2009; Park, 2005) reported that different ways of grouping are pivotal to make students experience authentic environment of 'Doing' inquiry activity. More challenging and motivated tasks for inquiry activity can be considerable factor to be reflected in planning student's 'Doing' inquiry activity as well. Students tend to lose their interest and motivation quickly with easy and routine science task, instead students who are familiar with 'open' inquiry activity show tendency to be challenged with new issues through which they can explore real environment of authentic scientific inquiry. Other physical context, such as enough time, appropriate materials and equipment, and space to explore, can promote students willingness to 'Do' inquiry activity.

When considering all factors for students' 'Doing' scientific inquiry, teachers need to plan inquiry lesson structurally. The most preferred teachers' roles for students who are familiar with 'open' inquiry can be 'helper' or 'guide' rather than 'provider' or 'problem solver'. For effective teachers' roles for students' 'Doing' scientific inquiry, teachers themselves need to have chance of reflecting on their understandings and practices through teacher professional development program, where teachers learn how to guide students to explore authentic scientific inquiry starting with framing inquiry questions and designing the investigation.

More specific professional development program, such as 'cooperative learning', 'authentic scientific inquiry', or 'scientific argumentation', must be provided for teachers to 'learn' how to guide and help to create authentic environment where students explore how scientific knowledge is constructed. This study can be used as the basis of developing clinical teacher professional development program through which teachers can be trained to teach how to implement open scientific inquiry in teacher education.

The scoring guides and rubrics (for abilities of framing inquiry questions and for abilities of designing investigation) employed to evaluate student's abilities of 'Doing' scientific inquiry in this study can be more developed to be used as evaluating tools for students' practices of inquiry activity. Teachers are eager to develop and employ 'authentic' evaluating tools (Chinn and Malhotra, 2002; Crawford, 2000; Flick, 1997), since there are few validated tools to evaluate students' practices of group inquiry activity. When teachers are skilled in using scoring guides and rubrics to evaluate students' abilities of framing questions and designing investigation, they in turn are guaranteed in guiding students to explore authentic environment of group scientific inquiry.

Overall, this study has implication in science education as well as gifted science education in that students need to have opportunities of explore 'authentic' group scientific inquiry which can be created by teachers themselves through their roles of effective roles such as 'guide' and 'helper'. To meet this goal, no doubt is more structured professional development program through which teachers reflect on their understandings and practices of 'how to guide students to learn scientific literacy pivotal.

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2010년 12월 31일 접수
2011년 1월 9일 수정원고 접수
2011년 1월 24일 채택

Appendix 1: Scoring guide for the ability of framing question

Criteria	Rubrics	
The level of inquiry question	-not stated, not inquiry question(not testable) *(ex) Is friction working in space? Can ice be hot?*	0 pt
	-question to get the knowledge only (ex) What is ozone layer? Why does human being dream?	1 pt
	-question to extend the prior knowledge (ex) Is there ozone layer in other planets? Is friction working in the water?	2 pt
	-requiring analysis, synthesis (generalization and prediction), or evaluation (ex) Why does ozone layer form? Why do clouds differ in shape?	3 pt
Preciseness of inquiry question	-not stated, cannot figure out its purpose (ex) Why do people react differently even to trifles?	0 pt
	-there is point what to explore but not scientific one (ex) Why does water has the property of polarity? Why do people dream?	1 pt
	-it is inquiry question, but with the use of terms which are not scientific one (ex) Does friction work in water? Do dolphins can understand what to do in their show?	2 pt
	-inquiry questions with the use of appropriate scientific terms	3 pt
The motivation of inquiry question	- not stated, cannot figure out its motivation	0 pt
	-it is inquiry question; but curious about observation itself (ex) I cannot see through ultraviolet ray, just curious. The stars are twinkle, just curious; cactus can block electromagnetic wave, is that true?	1 pt
	-it is inquiry question exploring phenomenon based on observation without conflict (ex) To what extent in gram does spider web be resistant?	2 pt
	-inquiry question exploring the followings; Conflict existing: there is contradictory concept between new and prior one, which means that there is new pattern discovered in phenomena, and there is conflict between prior knowledge and new one.	3 pt
Hypothesis from inquiry question	-not stated, cannot figure out if it is hypothesis or not	0 pt
	-hypothesis without validity	1 pt
	-hypothesis with weak validity	2 pt
	-hypothesis with strong validity	3 pt

Appendix 2: Scoring guide for the ability of designing investigation

1) Making hypothesis
1point: hypothesis without validity
2point: hypothesis with unclear variables stated
3point: hypothesis with clear variables stated

2) Preparing appropriate tools and equipments for experimentation
1point: inappropriate equipments prepared
2point: appropriate equipments are provided for experimentation
3point: appropriate equipments are provided for experimentation in detail such as amount of liquid or its characteristics

3) Considering variables
1point: not considering variables well
2point: developing independent variables with unclear dependent one and controlled one
3point: developing clear independent, dependent, and controlled variables

4) Lab safety
1point: no comment about lab safety
2point: comment about lab safety without precaution
3point: comment about lab safety with precaution

5) Controlling variable
1point: no controlled variables
2point: control variable but unclear
3point: control variable clearly

6) Planning the way of observation and measurement
1point: no or unclear statement about observation and measurement
2point: statement about observation and measurement but not detail
3point: clear statement about observation and measurement in detail

7) Interpreting the results on the basis of collected data
1point: no or unclear statements about interpreting the results on the basis of data
2point: simple statements about interpreting the results on the basis of data
3point: clear and concrete statements about interpreting the results on the basis of data

8) Stating the termination of experiments or its replication
1point: no statement about termination or replication of experimentation
2point: simple statement about termination or replication of experimentation
3point: clear and concrete statement about termination or replication of experimentation

9) Constructing the validity of experimentation
(Focusing on the consistency among inquiry steps rather than pursuing right answer)
1point: inconsistency among inquiry steps from making hypothesis to concluding the remarks
2point: partial consistency among inquiry steps from making hypothesis to concluding the remarks
3point: consistency among inquiry steps from making hypothesis to concluding the remarks