Science-Gifted Students' Scientific Inquiry Change in Online Argumentative Discussion

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Abstract: Argumentative discussion is one of the important components of an educational program, which allows students not only to learn the process of social negotiation through discussions, but also to improve students' overall research abilities. The purpose of this study was to examine a) the changes between inquiry of before-argumentative discussion and inquiry of after-argumentative discussion, and b) the connections between the inquiry changes and online argumentative discussion. This study analysed 726 messages in an online argumentative discussion, as well as in first research reports and second research reports. The results of the study indicate that science-gifted students' research abilities were improved through on-line argumentative discussion that provided them with feedback based on interactive discussions, and encouraged them to re-examine hypotheses and experiment processes. The science-gifted students showed knowledge and abilities for identifying simple errors in research processes and arguing problems in the flow of the whole logic of research.

Key words: on-line argumentative discussion, science-gifted students, scientific inquiry change

I. Introduction

In the 21st century, characterized by globalization and the age of knowledge and information, there is a great need for competent individuals who develop new science techniques and lead the future of nations. In line with this, laws that encourage education for science-gifted students have been recently established and, as a result, science-gifted students now have more opportunities to take special education programs. However, it is difficult to find special education programs, which expand and enhance science-gifted students' creative problem-solving abilities.

Scientific inquiry is being considered to be very important in an educational program for science-gifted students, as well as general students. Through the development of inquiry skills, students are expected to gain an understanding of concepts and content, and an understanding of the process of scientific inquiry (Abd-El-Khalick, Bell & Lederman, 1998). However, students work too often in the laboratory as technicians following "cookbook recipes", and they are unable to meaningfully summarize the important aspects of an experiment they have just completed (Bell *et al.*, 2003; Germann, Haskins & Auls, 1996; Tamir & Lunetta, 1981). Discussion on Physics Investigation Contest (DPIC) shows the possibility of good special educational programs for the development of science-gifted students' inquiry skills. DPIC resembles International Young Physicists' Tournament (IYPT), which was begun in the former Soviet Union. DPIC allows students to develop their scientific thinking and to improve their research abilities (KPERC, 1994). It also increases students' interest in scientific inquiry and enhances their competition abilities (KPERC, 1994). Through DPIC, students can experience scientists' research while solving real-life physics problems. Especially, an argumentative discussion in DPIC can make students learn the process of social negotiation through discussions and improve overall research abilities (KPERC, 1994). Their participation in discussion

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produces many instructive results from various sides that are difficult to get in normal lectures. The discussion is very important in terms of (1) its result and process, (2) participants' intelligence, behavior and attitudes, and (3) private things and common things that the discussion generates (Dillon, 1994). Small group discussion, particularly, gives students an opportunity to make their ideas clear, and create solutions to problems with other participants' opinions and self-examination (Driver, 1995).

Discussion on the learning of science makes it possible for students to realize the basis of explanation and the importance of reasons in science (Meyer & Woodruff, 1997). Through interaction with others or other groups, students can develop scientific means and consider the scientific process that makes models and theories. They can also experience the scientific knowledge-building process in a similar way that scientists practice. In DPIC, however, students seemed to find difficulties in expressing their own opinions, mainly because of the insufficiency of discussion time (Lee, 2003).

Unlike a general discussion, a critical discussion activity called 'argumentative discussion' involves re-analysis of data, re-experiment and incidental discussions with colleagues, as a way of helping participants prepare their replies to problems that other participants repute or bring up. Considering that not enough time is usually given to the discussion activity in practice, it would be needed to look into the possibilities of argumentative discussion in Web-based instruction. Web-based instruction makes self-directed learning possible, and promotes empirical knowledge composition through social interaction (Relan & Gillani, 1997; Romiszowski, 1997). It provides students with opportunities to experience various forms of interaction (Harasim, 1989; Hiltz, 1990; Romiszowski & Mason, 1996).

The interaction can be effectively made through on-line discussion in Web environments, which provide virtual space for real communication. Since on-line discussion is not restricted by time and space in general, it is possible for students to have self-examination and many-to-many interactions with other students (Berge & Collins, 1993; Harasim, 1990; Hoadley & Linn, 2000). Also, because the whole process of discussion can be recorded onto the computer, students can confirm the contents of the discussion, while teachers can easily look into the interactions between students easily (Hara, Bonk & Angeli, 2000).

Based on these points, the authors have adapted the concept of argumentative discussion in on-line environments, and have developed an on-line discussion system (ODS) for learning the investigation of physics (Lee, Son & Lee, 2003). Also, we have presented the science gifted students' interaction pattern in online argumentative discussion (Lee & Lee, 2004), and the characteristics of online argumentative discussion through the students' perceptions (Lee & Kim, 2004). Though this research could provide us with an outline of online argumentative activities of science gifted students, we could not understand how science gifted students made their inquiries. We think that it is very important to know how the inquiries of science gifted students are developed to advanced forms in online argumentative discussion. Thus, our research questions are: (1) What differences are there between inquiry of before-argumentative discussion and inquiry of after-argumentative discussion?; (2) How is online argumentative discussion connected with the inquiry change of science gifted students? In an attempt to answer these questions, we have analyzed queries and arguments shown in the argumentative discussion.

II. Research Process

A total of 23 science-gifted students in the Science Gifted Education Center at Seoul National University used ODS for two months, from November 9, 2002 to January 8, 2003. They participated in on-line argumentative discussion for 12 days, from December 24, 2002 to January 4, 2003. As shown in Table 1, they were involved in collaborative investigation, on-line argumentative discussion and face-to-face argumentative discussion. They were divided into four groups and made open scientific inquiries of the transmission of sound, electronic fan wing, soap bubble, boomerang airplanes and others. The science-gifted students presented their research reports twice - before and after on-line argumentative discussion. The science-gifted students posted 726 messages during on-line argumentative discussions. These messages and research reports were analysed to examine the inquiry process changes.

III. Results and Discussion

1. Inquiry process before the online argumentative discussion

In order to find out how science-gifted students might solve a given problem, their research reports were analyzed completely, but it seemed difficult to grasp detailed facts. In online argumentative discussion, it was possible to analyze science-gifted students' discussion process easily because the whole process of discussion was recorded on the computer. It was also possible to grasp how science-gifted students solve problems through social consensus.

We analyzed the inquiry processes and contents of the online argumentative discussion. In addition, the characteristics of science-gifted students are explored with the change of research process.

This report presents the results of an example of Group-2. The whole inquiry steps appeared faithfully and we could find more changes in the inquiry process of Group-2 than in any other group.

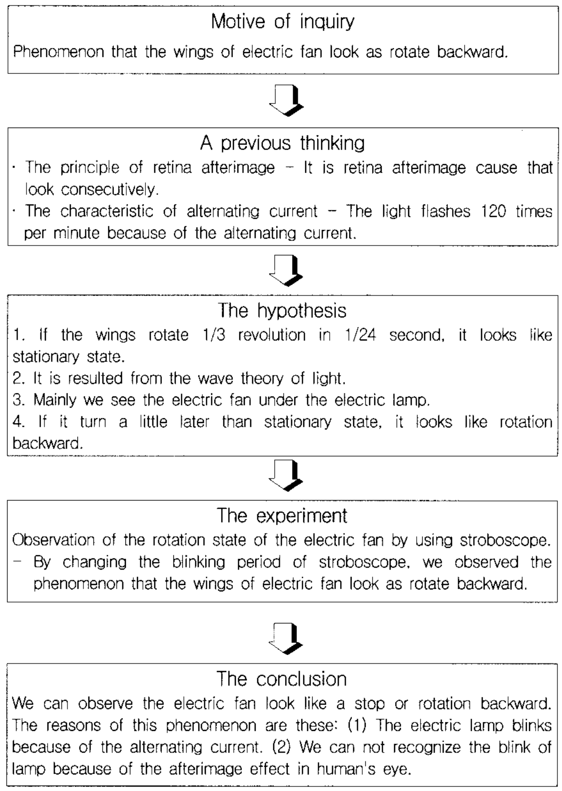

Fig. 1 *The steps of inquiry before the online argumentative discussion*

Table 1
Process of Overall physics argumentative discussion

Step	Schedule	Contents
Collaborative research	Nov. 9, 2002	· Introduction of Physics Argumentative Discussion · Selection of group and leader · Selection of Inquiry Subject
	~ Nov. 13	· Presentation of Subject choice report
	~ Dec. 20	· Collaborative investigation - Data investigation, construction setting, experiment design, experiment achievement, data analysis and report creation → Research report presentation
On-line argumentative discussion	Dec. 21	· Introduction of on-line argumentative discussion
	~ Dec. 24	· Preparation of on-line argumentative discussion
	~ Jan. 4, 2003	· Online argumentative discussion · Presentation of Corrected research report
Face to face argumentative discussion	~ Jan. 7	· Preparation and introduction of face to face argumentative discussion
	Jan. 8	· Face to face argumentative discussion

Group-2 investigated the condition and the reason why the wings of an electric fan seem to rotate backward with self-designed experiments. Figure 1 shows the steps of their inquiry process.

The students of Group-2 found that the wings of an electric fan looked like they were rotating backward, and hoped that they could scientifically find the reason of this phenomenon.

In order to understand their research process, it was desirable to examine their hypotheses. Their first hypothesis was that "If the wings rotate 1/3 revolution in 1/24 second, it will look like a stationary state." However, it was rejected through discussions among group members. This could be found in the following message.

I've heard that we need 24 frames per second in the exquisite movie. And I thought that we felt as if the wings of an electric fan looked like rotating backward because the human eyes cannot keep up with the speed of the wings. That is the principle of retina afterimage. However, these ideas were changed through the discussion with members. We had doubts how we could see the images discontinuously.

The students could solve a problem through discussion with their group members. Problem-solving seemed more difficult through individual inquiry, and easier through collaborative learning. The second hypothesis was related to the wave theory of light, and was rejected through the in-group discussion as well. The third hypothesis started with the observation that the electric fan was inside a room where the electric lamp was kept. The students assumed that the wings of an electronic fan looked like rotating backward due to the blink by an alternating current. The fourth hypothesis was related to the reason why the electric fan looks like rotating backward. They assumed that if the fan turned a little slower than the stationary state, it would look like rotating backward. Among these hypotheses, the third and fourth became the basic hypotheses of their investigation.

These hypotheses were based on the principle of retina afterimage and the characteristic of alternating currents. Although we do not look at the thing again after having looked at it, the image of the thing remains in the cells of our retina for a while. This phenomenon is called the retina afterimage. With this phenomenon, people could consider scenes of movie as continuous images, although they are not. Similarly, the students could find the reason why they could not recognize the blinks of an electric lamp.

The inquiry of the students was most affected by the characteristic of an alternating current. It made the students think that the electric lamp blinked about 120 times per a second, because an alternating current at home is 60Hz and so the current can become to be zero.

Based on these findings, the students designed an experiment using a stroboscope in order to find the reason why the wings of an electric fan looked like rotating backward. Changing the blink period of a stroboscope, they tried to find the state that the wings of an electric fan look like in a stationary state or rotating backward and came to the conclusion as follows.

We can observe that the wings of an electric fan look like a stop or rotating backward. The reasons of this phenomenon are: (1) An electric lamp blinks because of the alternating current; and (2) We can not recognize the blink of the lamp because of the afterimage effect in human's eyes.

2. Changes in inquiry process through the online investigative discussion

Students of other groups analyzed the inquiry report of Group-2 and carried out the critical discussion activity that was composed of questions, answers and counter-arguments. Whereas questions were usually presented in order to confirm the problem, the students raised many points of the issue through remarkable counter-arguments. Though simple counter-arguments could be replied right away, many assertions needed more time to investigate and conduct experiments again.

In the argumentative discussion on the inquiry of

Group-2, students of other groups presented many counter-arguments about hypothesis establishment. Group-2 students assumed that an electric lamp blinked because of an alternating current. However, they did not verify this assumption. They thought that this hypothesis was reasonable without a verification. Students of other groups argued that:

* *counter-argument about hypothesis establishment #1*
You described many concepts in the theoretical background. But you missed an important point. You did not tell us how this theoretical background was related to the phenomenon of an electric fan. Please explain the relationship between the theory and the phenomenon that the electric fan looks like rotating backward. And let me know how you chose these theories as the theoretical background.

* *counter-argument about hypothesis establishment #2*
You said that you could observe the backward rotation of an electric fan considered this as 'B' because of the blink of a lamp considered this as 'A'. But it seems to be a hasty conclusion. It is not logically certain that 'If A, then B'. 'If ~B, then ~ A' can be confirmed, but 'if ~A, then ~ B' can not be certain. That is, we can agree that if the electric fan does not look like rotating backward, the electric lamp does not blink. But we can not certain that unless the lamp blinks, the electric fan does not look like rotating backward.

They also indicated that there were some logical errors in explaining the relationship between the blink of an electric lamp and the backward rotation of an electric fan. This was an important indication in the argumentative discussion of Group-2. The students who participated in the on-line argumentative discussion presented many arguments about logical processes. One typical counter-argument made by them was that Group-2 students did not consider that an electric fan can look like rotating backward under the non-blink of an electric lamp as well. This can be found in the following example.

You said that the blink of an electric lamp was a main cause. But you did not experimentally prove it. That is a serious mistake. You had better try an experiment using a light without blinking, for example, a candlelight. But you did not. What did make *you not have these considerations?*

Group-2 students responded to these counter-arguments with their experiment result. They tended to present their responses to the counter-arguments with the hypotheses that they made. If they could not answer on the spot, they said that they would reply after conducting a supplementary experiment or an internal group discussion.

Because their scientific knowledge was poor in some cases, science-gifted students could not present appropriate replies to all arguments. However, they tried to make logical responses that were based on their observations and experiments.

The flowing of these argumentations was connected to the argument about the source of light. Students of other groups argued that the blinking phenomenon of a lamp would happen in the fluorescent light but would not happen in the incandescent lamp.

Group-2 students did not simply present the facts that they knew. Rather, they presented examples that could confirm through experiments. That is, the students did not persuade others without justification, but presented the results of actual experiments or logical evidence.

In the first report of Group-2, they said that they observed the wings of an electric fan looking like rotating backward in the experiment with a stroboscope, and they presented the blinking period in the stationary state. Then the students of other groups requested the analytic condition that the electric fan looked like rotating backward. In responding to this request, Group-2 students conducted a new experiment during the online argumentative discussion and presented the condition that represented the quantitative relationship between the number of times that an electric fan looking like in a stationary state, the blink period of a stroboscope and the angular velocity of wings of an electric fan. This showed that, when the students were requested to explain the contents that they did not consider, they revised their inquiry process. As a result, their inquiry was developed into an advanced form. They could defend themselves against others' counter-arguments. The following example shows how a response was made in this situation:

* *Question*

When the period of blink may be long, that is, if it twinkles 1 times per a second, could we observe the electric lamp looking like rotating backward?

* *Answer*

In my corrected report, we came up with the relationship like this: $K\omega a = 2\pi N$*, where* a *is a number of wings,* ω *is an angular velocity. And* K *means that* the number of times *that looks like doing stationary, and* N *means the blinking number per a second of an electric lamp.*

Because the rotation of wings of an electric fan has high angular velocity, if N *becomes 1,* K *becomes a fraction number. Thus, we can not observe the backward rotation.*

As shown above, Group-2 students re-examined their research result through the online argumentative discussion and they added additional processes of logic in order to support their arguments. They carried out additional experiments and analyzed data from their experiments quantitatively. This implies that the students' research abilities could be improved through on-line argumentative discussions.

The inquiry process of Group-2 was changed in two parts. The first part was related to carrying out additional experiments. Group-2 students presented the hypotheses that a fluorescent lamp blinked because of an alternating current and the electric fan looked like rotating backward in a place with blinking light. To prove these hypotheses, they designed and conducted an experiment using a stroboscope. However, students of other groups raised a serious argument by pointing out that Group-2 students did not confirm whether the electric fan would look like rotating backward without the blink of a lamp. To respond to this point, Group-2 students conducted an additional experiment, in which they observed the rotation of an electric fan under candlelight. Although these efforts did not influence the conclusion of the inquiry a lot, they made the logical system of an inquiry clearer. The second change appeared in the conclusion of the research. Group-2 students examined the observation that the electric fan looked like rotating backward using a stroboscope. Through this experiment, they presented a qualitative condition in that the electric fan looked like rotating backward. Although they wanted to find the exact condition, they could not find it. After they were asked by other students to find the condition, they tried to find the relationship between the period of blink and an angular velocity of an electric fan. This means that it resulted from other students' request, even though they also wanted to know this relationship before they were asked. Figure 2 indicates the changes of inquiry process that came out through the online argumentative discussion.

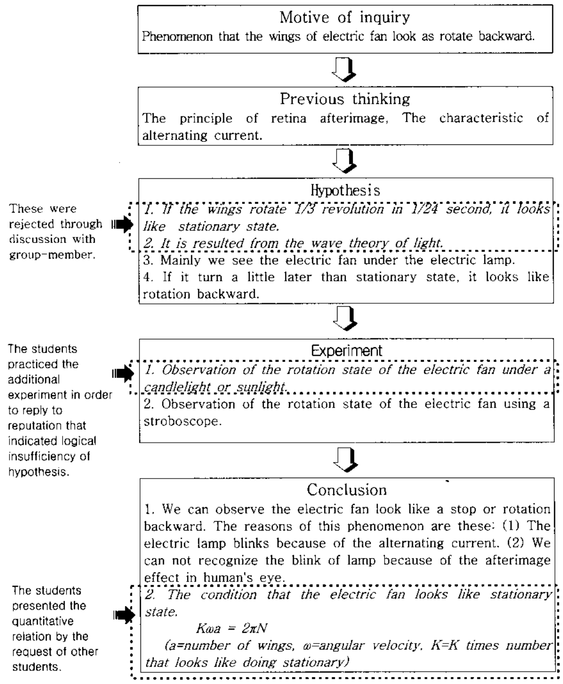

Fig. 2 *The changes in inquiry that came out after the online argumentative discussion*

IV. Conclusion

Collaborative discussion can develop students' overall research abilities, foster their systematizing talent and cooperative spirit. Through the discussion activity, science-gifted students can learn the process of a social mutual consent. To increase these educational benefits, we have developed an online discussion system for learning physics investigation, which allows science-gifted students to experience the collaborative discussion activity. The study reported in this paper examined the changes of inquires by the online argumentative discussion and presented how the online argumentative discussion was connected with science-gifted students' inquiry.

It was found that students presented many counter-arguments about logical errors in the establishment of hypotheses. Science-gifted students did not persuade others without justification. Their arguments were always founded on logical bases. In particular, they tried to make logical responses that were based on the results of experiments or logical evidence. It was also found that the online argumentative discussion made their scientific inquiry be revised. In order to defend other students' counter-arguments. Group-2 students carried out additional experiments with candlelight. With the result of this experiment, they could make their inquiry more definite. In the first research report, Group-2 students presented their research results in a qualitative way. Other students requested a quantitative experiment through the online argumentative discussion and Group-2 students inserted the requested condition in their revised research report. Through the online argumentative discussion, science-gifted students' research skills have been improved and their research could be reported in a complete form, which seems to be the best positive effect of the online argumentative discussion.

However, there are things that need to be improved in the students' argumentative discussion. For example, the students did not argued actively about the reason why the electric fan looked like a stationary state or rotating backward under a blinking light. Although they did not give a full explanation about it, other students did not raise any question or counter-argument which required a clear explanation. It could weaken the effect of the online argumentative discussion. While we did not present the reason for it in this paper, we assumed that it would be related to science gifted students' self-respect. As it is a very important aspect in online argumentative discussion, further studies are recommended to find out more about the students' self-respect.

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