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Analysis of Stability in Verbal Interaction Types of Science-gifted Students

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ABSTRACT
Science inquiry activities carried out in a small group are learner-centered activities operating under the premise of collaborative interaction between members through various types of communication and consultation in the process of resolving issues.The changes in the types of interactions in the three exploratory activities targeting science-gifted students were analyzed using the Social Network Analysis (SNA). As a result of analyzing eight small groups, it was possible to divide the interaction types into two groups, namely, the alienation retaining type—where the type of interactions was retained from start to end—and the alienation changing type where the types of interactions changed. First, regarding active interactions between three members, the remaining students turned out to be alienated and could not participate in further inquiry activities. Second, changes of types occurred in accordance with the leaders' central positions. On the basis of this study, it is expected that future analyses will show how the type of interaction changes according to the level of inquiry or familiarity status with the inquiry topics. In addition, it is expected that studies about guidance and feedback of teachers and new students' participation in the interactions will follow.
Keywords: social network analysis, verbal interaction types, science-gifted students

INTRODUCTION

Science inquiry activities carried out in a small group are learner-centered activities operating under the premise of collaborative interaction between members through various types of communication and consultation in the process of resolving issues. A lively interaction among the members of a small group while conducting the explorative processes is known to be effective in terms of understanding science concepts (Lumpe & Staver, 1995), science inquiry skills (Kim et al., 2001), and the degree of science achievement (Johnson &

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State of the literature

- A lively interaction among the members of a small group in inquiry class is known to be effective in terms of understanding science concepts and science inquiry skills.
- Many studies analyzed the communication or verbal interactions between members with a focus on the microscopic properties of the interactions.
- However, it is difficult to quantitatively determine the nature of the dynamic interactions occurring between members in the inquiry activity.

Contribution of this paper to the literature

- The reason why changes of interaction type within a small group can take on a variety of forms is the dynamic nature of the inner characteristics of a small-group members.
- In order it achieve active communication and cooperative interactions, it is necessary to have a member at the center position with the qualities that can provide the clues needed to solve problems.
- It is necessary to provide opportunities for all members to participate equally through a suitable role circulation or role distribution.

Johnson, 1985). These small-group activities provide members with the opportunities to examine and criticize a variety of views and arguments (Fox, 1995), improve self-directed learning skills (Slavin, 1995), and have positive influences on academic achievement and learning attitude of learners (Johnson & Johnson, 1985; O'Donnel & King, 1999).

Inquiry activities that address challenges through cooperative interactions among the members in science education have been highlighted, and studies that analyze the effects and characteristics of the interactions that appear during science inquiry activities have followed (Lonning, 1993; Moher et al., 2008). Recently, studies that analyzed the communication or verbal interactions between members with a focus on the microscopic properties of the interactions have also been conducted (Abraham, 1976; Baker et al., 2009; Chin & Osborne, 2010; Sim & Yusof, 2012). These studies mainly identified the characteristics and effects of the interactions that appeared in the inquiry activities in relation to science achievement, the ability to explore, and the degree of satisfaction, or analyzed the effectiveness of the interactions according to various circumstances—such as cognitive levels or team compositions. However, it is difficult to quantitatively determine the nature of the dynamic interactions occurring between members in the inquiry activity, because these studies were limited to quantitative analyses based on the framework for linguistic analysis of the conversation content shared during the interactive process. In other words, studies have rarely been found that structured the types of interactions based on the individual positions and roles occupied within small groups and taking into account the relationship with other members.

In this study, the Social Network Analysis (SNA) was used in order to structure the types of interactions between members. SNA is a method that can visualize the type of group communication through quantitatively analyzing the links between the members that appear

during information exchange and communication (Krackhardt, 1992; Storberg-Walker & Gubbins, 2007). The analysis begins with identifying the true nature of any phenomena that is expressed in the relationships between individuals without being limited to the dimension of personal characteristics. Thus, the method focuses on the analysis of relationships formed between the individual members apart from the statistical methodology that identifies cause and effect relationships between the existing individual characteristics (Emirbayer, 1997). Therefore, it is very effective for dynamically and systematically representing the relationships based on the entire structure of the group and the position and role of each member (Chang, 1997).

Verbal Interaction and Science-gifted Students

In this study, we focused on the science-gifted students' verbal interaction. We have two reasons for choosing science-gifted students as a sample for this study. First, recent studies emphasized the convergence of science, the role of collective intelligence in scientific study (Noor, 2012). The communication skill is the core competency for the multidisciplinary scientific study (Brownell et al., 2013). The face-to-face interaction and talking to peers (verbal interaction) is the core of communication and improve students' communication skill. Second reason is that science-gifted students may possess limited verbal interaction skills because of limited social interaction ability and Confucian culture in Korea. Many studies have warned that highly gifted children have some trouble in peer relationships (Lovecky, 1995; França-Freitas et al., 2014; Gross, 2006). In addition, students are not active to lead the communication because of receiver-centered communication in the Confucian culture. Thus, we were concerned that our science-gifted students may possess limited verbal interaction skill even though they must possess good communication skills in the group based scientific studies. In addition, we should be able to identify the students with limited verbal interactions and the students with good verbal interaction skill for leadership of the group-based work so that we can provide them for appropriate activity or roles in the group based work.

To this end, we examine students' verbal interaction using social network analysis. One key of our methodology is that we used the different contexts of inquiry. We believe that students' verbal interaction does vary across contexts, then, it is concluded that the verbal interaction is influenced by the contexts. However, students' verbal interaction does not vary across contexts; we can conclude that the verbal interaction may not be influenced by the contexts but by the individual's competency. The social network analysis method has been used in studies on interaction; however, they showed very limitation of study. For example, previous studies (Kim & Kim, 2015) analyzed the types of interactions that appeared in the inquiry activities using SNA. This study analyzed eight interaction types that appeared in inquiry activities. In addition, the study targets were divided into alienated and participative groups based on the number of members who either participated or were alienated. The alienated type was identified when any one of the five members was alienated; the participative type was identified when all five people participated in the interactions. However, existing studies did not analyze whether the stability of the interaction type was

maintained during the process of continued inquiry activities. Thus, this study analyzed whether the interaction type changed during continuous inquiry activities. Through this analysis, it was expected that plans for alienated students to participate in the interactions and plans to improve interactions could be provided.

METHODS

Subjects

The subjects of this study were first-year middle school students from three classes of the Daegu Science Gifted Education Institute in South Korea. It must be noted that there are many gifted-student centers in Korea. For example, our sample was affiliated to the gifted-students center supported by local offices of education (e.g., Daegu City). Other gifted student centers are government-supported center, and KOFAC supported center (Korea Foundation for the Advancement of Science and Creativity). Our students were selected from students who received education for the science gifted at elementary schools through tests aimed at creativity and problem-solving abilities. Among the 60 students who participated, 46 were boys and 14 were girls. Each small group consisted of five members who had not been previously acquainted with each other by replacing the already acquainted ones with members from other small groups. The changes in interaction type in the eight small groups were investigated, except for small groups in which absences occurred during the study period.

Inquiry Program

The inquiry program was designed as an open inquiry for the members of the small groups to interact with each other, to plan the course of the inquiry, and to carry out cooperative inquiry learning. Considering the characteristics of the science-gifted students, topics that could not be accessed during the regular curriculum such as “enzyme reactions,” “cricket ranks,” and “drosophila behaviors” were chosen.

The inquiry program was divided into eight steps, and the information for each step was as follows (**Table 1**): The introduction step provided the study motivation and stimulated curiosity by showing the phenomena directly through teacher activities. In the observation step, pilot experiments were reproduced for multi-angled observation in each small group. In the generating problems step, after having prepared for the problems to be explored based on the information observed in the small group, a single inquiry topic was decided through a discussion in the entire group. In the formulating hypothesis step, the subjects were asked to set up the hypothesis that could address the given inquiry problems.

In the step designing the experiments, the subjects were asked to select a hypothesis that could be verified by experiments among the various hypotheses, and to design specific experimental methods and procedures that could prove it. In the data collection step, the subjects were asked to record all the data obtained through the experiment by quantifying

Table 1. Key activities illustrated by the inquiry step (e.g., enzyme reactions)

Inquiry step	Key activities
Introduction	Show what happens when you mix water and hydrogen peroxide with a 1:1 ratio and add fresh potato pieces to the mix.
Observation	Observe carefully what happens when you mix water and hydrogen peroxide with a 1:1 ratio, add fresh potato pieces, and then record what happens as accurately as possible.
Generating problems	Let students set up the issues they want to explore based on the things they observed.
Formulating hypothesis	Let the students select one of the inquiry issues recorded earlier and set up as many hypotheses, which can explain the issues, as possible.
Designing of experiments	Let the students select the most plausible hypothesis among the proposed hypotheses and specifically design experiments that can verify the hypothesis by taking various factors into account.
Data collection	Let the students organize the data obtained from the experimental results.
Data transformation	Let the students interpret the obtained data by converting them to facilitate understanding.
Drawing conclusion	Let the students draw conclusions based on the experimental results.

them. In the data transformation step, they were asked to clearly interpret the results based on the presentation of diverse opinions via the process of transformation of the quantitative data collected in the experiments to tables or graphs. In the drawing conclusion step, the subjects were asked to make conclusions on the basis of the hypotheses built from the data collected in the experimental results.

The inquiry step addressed the issue through minimizing the involvement of teachers and the students' active interactions. The selected inquiry topics and validity of the inquiry worksheet were completed by the small group through several verification processes by combining the opinions of four science education experts.

Data Collection and Analysis

The present study conducted three inquiry activities targeting the science-gifted students from March to June. The inquiry activities were in the order of "enzyme reactions," "cricket ranks," and "drosophila behaviors." Five people were in each small group, and all the activities were recorded and analyzed using NetMiner 4 by transferring the recorded data.

Measuring the frequency of verbal interactions

Most of the interactions that appeared in the science inquiry activities were made in verbal form, while non-verbal interactions such as facial expressions, gestures, and behaviors also occurred. In this study, verbal interactions without direct relation with the instructive information and non-verbal interactions, including chats, were excluded based on a previous study (Hogan, 1999), and the frequency of the remaining verbal interactions was measured. The measurement criteria were such that a response to the suggestion or opinion of another

member was counted as one; each response by a member was counted as one when the responses were made by several members at the same time. If the same response was repeated, it was counted as one; any murmuring not responded to by other parties, incomprehensible speaking, information unrelated to the task solution, and the interactions with teachers were excluded from the frequency measurement. In order to ensure that the frequency of interactions was properly measured, four science education experts checked the transcription repeatedly until the agreements reached to 90%.

Matrix Transformation and Visualization

Measured interaction frequencies were expressed in a matrix, which is one of the most basic ways to express the data for the Social Network Analysis (SNA). It displays the specific value in a cell, where a row and column meet, and represents the relationship between row and column. In general, whether a relation exists or not can be confirmed by the differentiation between 1 when a relation is present and 0 when a relation is not present. However, to express the quality of a relationship beyond its presence or absence, the degree of relation is expressed with the quantified frequency. However, a permuted matrix could become very complex when there are a number of members or relation frequencies; thus, the appropriate cut-off value is prescribed to express the values above this cut-off as 1, and the values below as 0 by conversion (Sohn, 2010) depending on the research purposes. **Table 2** is an example of the permuted matrix showing raw data measuring the frequency of verbal interactions. Here, the number 115 in the first row and second column refers to the frequency of responses by Student 2 (S2) to the suggestions of Student 1 (S1); number 98 in the second row and first column refers to the frequency of responses by S1 to the suggestions of S2. The sum of frequencies of interactions by all five members (S1–S5) was 743, the average of total interaction frequencies of one member with other members was 148.6, and the average interaction frequencies of one member with the other four members was 37.2.

Here is the example of students' verbal interaction.

(Case 35) Student 1, 2, 5's verbal interaction (at enzyme reactions activity)
S1: What about raw potato? What about the boiled potato? Do you think that the boiled potato makes same amount of air bubble? I think that boiled potato cannot make air bubble…
S5: Right, the raw potato makes more air bubble.
S2: Okay, then, raw potato
S1: I do not think that too high temperature is not good because the enzyme will be spoiled in high temperature.
S5: Right, the enzyme will be spoiled in high temperature.
S1: What else?
S2: How can we use the boiled potato for this experiment?
S1: We can boil one
S2: Do we have alcohol ramp to boil? Do you think we can? How? I am skeptical.

Table 2. Example of permuted matrix on the frequency of verbal interactions

Student	S1	S2	S3	S4	S5	Subtotal
S1	0	115	18	46	58	237
S2	98	0	9	40	72	219
S3	27	5	0	2	3	37
S4	30	38	0	0	24	92
S5	54	85	0	19	0	158
Subtotal	209	243	27	107	157	743

Table 3. Example of dichotomy matrix on the frequency of verbal interaction

Student	S1	S2	S3	S4	S5
S1	0	1	0	1	1
S2	1	0	0	1	1
S3	0	0	0	0	0
S4	0	1	0	0	0
S5	1	1	0	0	0

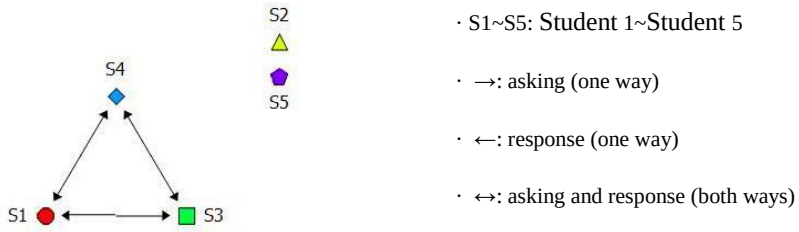

Figure 1. Example of verbal interaction graph

S5: We can cut the whole potation and use only some parts.
S2: Do you think we can?
S1: I believe we can
S2: Do you think that we can use the enzyme continuously?
S1: Sure, but I think that the amount of air bubble decrease as time goes by.
S5: But, I can see the air bubbles are appearing continuously.
S1: But, the amount of air bubble appeared at the first time were largest. What else? Do you think that we can boil it using a beaker?

Based on these analyses, this average (37.2 times) was converted into a dichotomy matrix (**Table 3**) in order to structure the types of interactions by group. In the data analysis of the dichotomy matrix, 1 was considered to have interactions, while 0 was considered to have no interactions according to the same meaning and criteria of the dichotomy matrix in general.

The data converted to the dichotomy matrix were visualized using NetMiner 4 (**Figure 1**), and the interactions of the small groups as well as the degree of connections between the members, density, and the numerical properties of the centrality were analyzed.

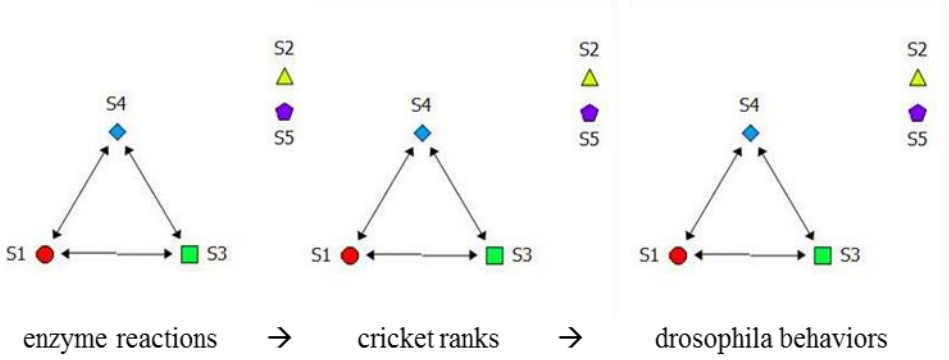

Figure 2. Alienation retaining type

RESULTS

The changes in type of interactions among the small groups during the three inquiry activities could be divided largely in two cases. These were cases in which the type of interactions per group did not change with the topic and cases in which the type of interactions changed. Out of these, the changing interaction type was further divided into four subcases. Based on the criteria of dividing the type of interactions into alienated and participative type in a previous study (Kim & Kim, 2015), the changes of interactions in a small group were named as follows: the case in which the interactions did not change and the alienated member remained was named "alienation retaining type," and the four cases where the interactions changed were named "alienation expansion type," "alienation expansion returning type," "alienation participation expanding type," and "alienation participation switching type."

Alienation Retaining Type

The alienation retaining type represents the case in which the verbal interaction type between the members was maintained without change during the three inquiry activities. In this type, three out of five members, S1, S3, and S4, formed a triangle interacting in two ways while the other two, S2 and S5, remained alienated without interaction (**Figure 2**). That is, the degree of connection for S1, S3, and S4 was 2, showing the interactions with three members, while the degree of interactions for S2 and S5 was 0, not showing any interactions.

The alienation retaining type, where two out of the five members were isolated and the remaining three were interacting, showed the same form in all inquiry activities and occurred at low frequency in general. This type seemed to be caused by a display of interactions unrelated to the given tasks showing uncooperative attitudes and negative and oppressive ways of speaking by one of the three students who were interacting. This led to an atmosphere where two members did not dare to take part in group activities. It is presumed that this kind of situation not only interfered with aggressive participation of the members but also deteriorated the quality of the overall interactions.

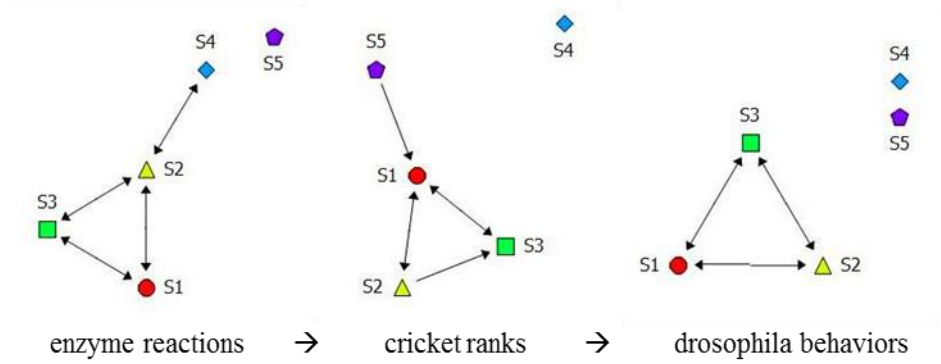

Figure 3. Alienation expansion type

In this case, it is believed that the aspects of interactions and the numeric values, such as the degree of connections and density between the members, could have been different if there had been a member in the position of a leader who played a central role in renewing the atmosphere by adjusting the attitudes of uncooperative members or inducing positive interactions. That is, in the cases of small groups without leaders, the frequencies of interactions were significantly lower—showing poor results, such as not being able to answer correctly to the question in the experimental activity data—reflecting the results of a previous study (Ku et al., 2007). These features of the alienation retaining type can be considered an example of the negative aspects that can appear in student-directed laboratory activities where teacher intervention is minimized for the sake of lively interactions among students. Therefore, even in the case of student-led inquiry activities with minimal teacher intervention, teachers may need to intervene with frequent checks so that the students can participate in-group problem-solving activities and help maintain a positive atmosphere and cooperative interactions.

Alienation Expansion Type

The alienation expansion type represents the case in which the structure changed from one alienated member in the first and second inquiry activities to two alienated members in the third inquiry activities. This alienation expansion type showed up in two small groups (**Figure 3**).

In the first inquiry activities, the structure of the small groups was as follows: except for S5, four students, consisting of a center figure S2 and interacting members S1, S3, and S4, were interacting. S1 and S3 were engaged in two-way interactions. In the second inquiry activities, the whole structure remained, but there were changes in the positions of the individual members as follows: the positions of S1 and S2 were reversed resulting in a shift of the central student from S2 to S1; S5 who was alienated in the first inquiry activities entered into the interactions, and S4 who used to participate in the interactions was alienated. In the third inquiry activities, S5 who had previously entered into the interactions was again alienated;

three students, S1, S2, and S3 were the same as in the first inquiry activities and participated in two-way interactions forming a triangular structure with each other; S4 and S5 were alienated and did not form interactions, showing the structural differences from the first and second inquiry activities.

Changes in the alienation expanding type showed a shift in the position of alienation as the connection, which used to be the only connection with the central member, was cut off in accordance with a change of the central member. It is considered that the two members who were connected with the central members were alienated as both central members lost their central positions during the first and second inquire activities. In other words, the central members were not playing an exclusive role leading the group activities but accounted for almost equal status with the other two members engaging in the decision making needed for the inquiry activities together. While taking an auxiliary position in the inquiry activities, the other students took on the central positions in other inquiry activities, showing the change in the central position.

The causes for these changes could come from the characteristics of the members, but, as suggested earlier, it appears that members suitable for the central positions in the small-group networks are necessary, especially those with qualities that can induce task resolution by providing troubleshooting solutions or alternatives and by making appropriate judgments via the collection of opinions from other members.

Alienation Expansion Returning Type

The alienation expansion returning type had a structure with one alienated member in the first inquiry activities, but with two alienated members in the second inquiry activities, thus showing an increase. In the third inquiry activities, however, the structure went back to the first form. This type was observed in one small group. The structural aspects of the alienation expansion return type appeared by topic and are described as follows (**Figure 4**):

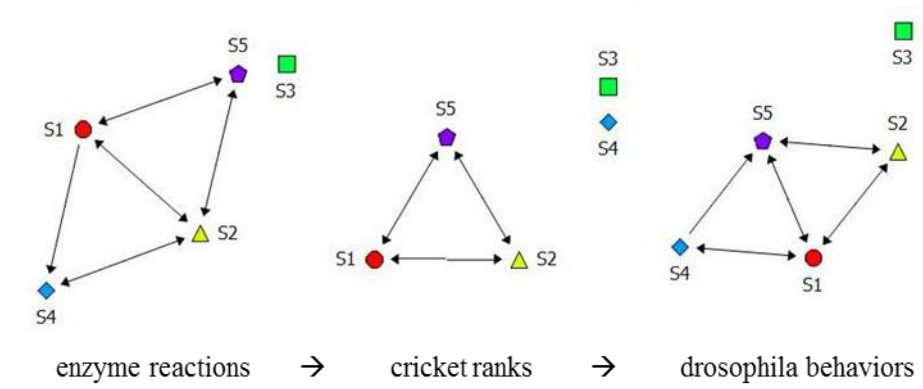

Figure 4. Alienation expansion returning type

In the first inquiry activities, four students were connected forming a rhombic structure except for S3; among the four students, S4 and S5 were not in a direct relation with each other. In the second inquiry activities, S4 who used to form a rhombic structure dropped off removing an axis, leaving S1, S2, and S5 to form a triangular structure. S4 whose interaction was cut off played a crucial role in the structural change by moving into the alienated group where S3 was located. In the third inquiry activities, the same structure as in the first reappeared, as S4 joined the interaction again. However, internally there was a difference as S4 and S5, who did not show interactions in the first inquiry activities, were now connected while the connection between S2 and S4 was broken. In addition, the changes in the positions of the individual members were revealed; S2 and S1 both had connections with three members in the first inquiry activities while these positions moved to S1 and S5 in the third inquiry activities.

In the alienation expansion returning type, all the members, except for some alienated members, involved in inquiry activities were on nearly equal footing without any members appearing in the center of interactions. The types of interactions in the first and third inquiry activities were maintained as a whole, regardless of some variations in internal position. In contrast, the number of participating members could influence the activity performance, which was the lowest in the second activity with two alienated members. This was consistent with the studies by Jeong et al. (2013), showing that static relationships existed between the performance of groups in small-group activities of science-gifted students and the interactions between the members. This pattern could also be understood in the same context as the studies by Ku et al. (2007), demonstrating that the degree of achievement and inquiry abilities appeared high in the case of groups where many interactions happened in MBL experimental classes. In addition, it is consistent with the study by Seong & Choi (2007), showing that it was desirable to form homogeneous grouping in the inquiry experiment classes based on interactions, since there was no leader position member with a central role in the interactions and the members were playing almost equal roles in the numerical characteristics except for the alienated members. The study by Lim et al. (2014), which analyzed the structure of interactions of team leaders in online team projects, reported that higher scores were reported when all the team members interacted evenly. Thus, in the case of the alienation expansion returning type, this study obtained similar results as previous findings, suggesting that the members interacted relatively evenly except for some alienated members.

Alienation Participation Expanding Type

The alienation participation expanding type represents the case in which the types of inquiry activities changed from the first to the second inquiry activities, and this changed type lasted until the third inquiry activities. The aspects of the thematic verbal interactions of the alienation participation expanding type are as follows (**Figure 5**):

In the first inquiry activities, four students were connected, except for S4. Three students (S2, S3, and S5) interacted with each other through S1 at the center, and there was no

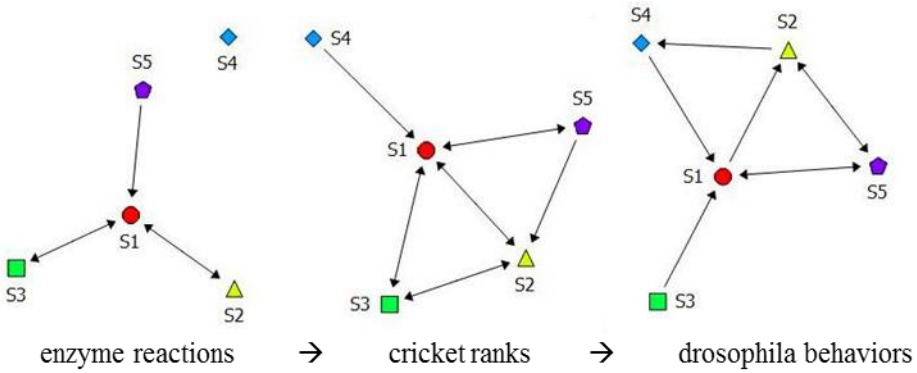

Figure 5. Alienation participation expanding type

connection between S2, S3, and S5. In the second inquiry activities, S4 who used to be alienated formed interactions with all members after being linked to S1. In addition, S2 and S3 who did not have interactions now interacted in two ways, and S2 and S5 also formed interactions in one way. In the third inquiry activities, there were some changes in the positions of individual members, as the positions of S3 and S4 were switched, even if the second type of inquiry activities remained unchanged.

In the inquiry activities, it was confirmed that S4 played as much of a role as S1 in the decision making for task resolving by providing appropriate comments whenever necessary. As described above, in the alienation participation expanding type, S4 at first appeared passive in the interactions in a marginalized position but contributed to the changes in the network structure by gradually forming connections with the other members. The alienated members in this type, unlike the students with no motivation for inquiry or with a passive attitude, played a helping role in leading the group activities into success along with S1 in the leader position, by suggesting ideas necessary for task resolving and by participating in the moment of important decision making even if they appeared somewhat taciturn due to the role of recording the worksheet.

Alienation Participation Switching Type

The alienation participation switching type, which is the case of showing mutually different verbal interactions by inquiry topic, was observed in three small groups. It has a form in which its network structure changes as the members alienated first become participants or the participating members become alienated (**Figure 6**).

In the first inquiry activities, S2 was in a state of isolation while three students—S3, S4, and S5—were connected with S1 at the center. S4 was connected with the central student S1, but S3 and S5 had only one-way interactions. In the second inquiry activities, S2 who used to be alienated caused structural changes by being connected to the central student S1. In this process, as S5 formed new interactions with S4 with whom there used to be no connections after cutting off the connection with S3, the triangular structure consisting of S1, S3, and S5 in

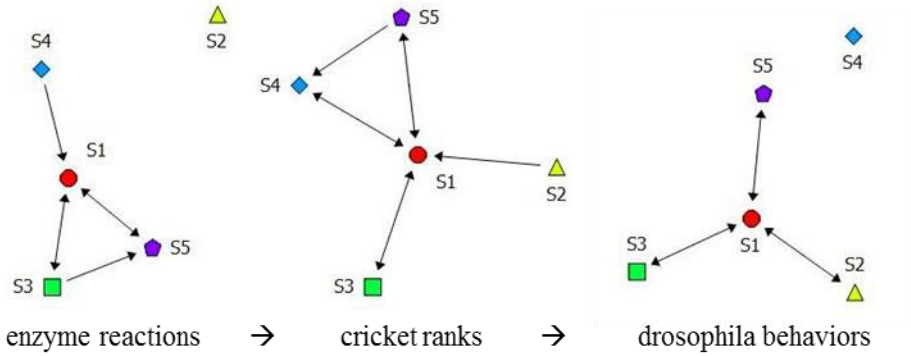

Figure 6. Alienation participation switching type

the first inquiry activities changed into a structure consisting of S1, S4, and S5 in the second inquiry activities. The triangular structure disappeared as S4, who had formed interactions with S1 and S5, dropped off leaving the connections by the remaining students.

In the alienation participation switching type, the form of interaction type changes with every topic; in the first inquiry activities, there was only one alienated member; but in the second inquiry activities, all the members interacted actively showing connections; and in the third inquiry activities, a new member was alienated. The frequency of interactions was generally high. In particular, it was the highest in the second inquiry activities in contrast to the below average inquiry worksheet score for the second inquiry activities that was lower than the whole group average except. Even if there were students who were in central positions, they neither asserted their own opinions nor played leading roles in group activities, and the proceedings were smooth, in a democratic atmosphere, and with free communication.

However, given the lack of suggestions for direct ideas needed to perform specific tasks and the tendency of determining the direction of task resolution by the agreement of all small-group members rather than specific members, effective group activities were not reached. In addition, the relaxed atmosphere—without the burden of each student performing a role—might have had a negative influence on performance leading to the inability to concentrate on the task and alienation of some members. Therefore, it is considered a case where the presence of the member at the center was only nominal. This is similar to the results of the study by Jeong et al. (2013), showing that the shared type structure without leaders were slow in task resolution due to the inefficiency of conducting tasks and unnecessary interactions, regardless of the high rate of communication. Therefore, in the case of the alienation participation switching type, it is expected that the activities of this type, having the atmosphere of mutually cooperative work, can lead to immediate results if members exist who can provide critical clues to task resolution or connect to strategic ideas by drawing out mutually cooperative role sharing and by collecting the opinions of members based on a democratic atmosphere, such as respecting the opinions of members and resolving the issues through total agreement.

Discussions

In this study, we explored the character of the science-gifted students' verbal interaction using social network analysis. Given that recent studies emphasized the convergence of science, multidisciplinary study with good communication skills of scientists, the verbal interaction is the core competency that science gifted students should possess. However, given that gifted students may have some trouble in peer relationships and that the students in in the Confucian culture may be passive in verbal interaction, it is needed to explore the character of the science-gifted students' verbal interaction. Here, we discuss our results.

First, it is presumed that the reason why changes of interaction type within a small group can take on a variety of forms is the dynamic nature of the inner characteristics of small-group members where interactions take place rather than the inquiry topic itself. That is, the roles of the members may be the most important factors in determining the success of group activities. For a successful group, the balance between the roles of the group members must be well maintained (Belbin, 1981), which is similar to the learning process occurring in small groups (Jeong et al., 2009).

In particular, in order to achieve active communication and for cooperative interactions to take place, it is necessary to have a member at the center position with the qualities that can provide the clues needed to solve problems. This can be a member who typically exists in a successful small group and has a similar role to that of the "promoter of reflection" described by Hogan (1999), who stimulates the members and facilitates the reflective thinking in order to improve the quality of ideas, and the "implementer" described by Belbin (1981). In addition, it can be seen as being a similar concept to the inclusive leader type (Ku et al., 2007) who leads the group activities in a positive direction by proposing his or her own opinions appropriately and combining the feedback from members. In contrast, in the case of small groups in which cooperative participation is impossible, the following members exist: a bitter and poignant promoter of acrimony, who applies abusive words and actions; a promoter of distraction, who acts out behaviors irrelevant to the task; and a promoter of simple task completion or unreflective acceptance of ideas. These members are only interested in a fast pace rather than the refinement of opinions for task resolution at a high level (Hogan, 1999).

Therefore, it is necessary to have a member with a central role who creates a permissive atmosphere in which members attend to each other's opinions and discuss things from equal positions and can lead to cooperative interactions—such as opinion suggestion and information exchange—which can lead to task resolution. That is, in the case of shared type structures, where every member participated in decision making without the leading member making the decision, it turned out that task resolution was rather slow due to the inefficiency in carrying out tasks and too many unnecessary interactions.

However, if the members of the central position do not perform their roles properly regardless of their presence, it can lead to the alienation of some members, which can have a negative impact on performance (Jeong et al., 2013). Considering that the presence of more

alienated members can lead to lower frequency of interactions or performance in inquiry tasks, teachers should frequently check and provide guidance in order to have a group structure where all the members can actively participate and interact seamlessly. In addition, personal characteristics are factors that need to be considered in small-group composition if passive and taciturn students are included or tasks need to be solved in close interactions in a state of unfamiliarity.

On the other hand, in the cases of alienated members, health problems (such as a cold that hindered active participation or the properties of roles such as worksheet recording duty) were pointed out as problems. Members recording worksheets showed a relatively low frequency of interactions because their activities consisted mainly of asking back or confirming the spoken contents of members instead of direct participation in opinion suggestion or information exchange. Thus, it is necessary to provide opportunities for all members to participate equally through a suitable role circulation or role distribution.

CONCLUSIONS AND IMPLICATIONS

The changes in the types of interactions in the three exploratory activities targeting science-gifted students were analyzed using the SNA. As a result of analyzing eight small groups, it was possible to divide the interaction types into two groups, namely, the alienation retaining type—where the type of interactions was retained from start to end—and the alienation changing type where the types of interactions changed. The conclusions for these types are as follows.

First, regarding active interactions between three members, the remaining students turned out to be alienated and could not participate in further inquiry activities. This formed the atmosphere in which one of the three members habitually carried out interactions irrelevant to the tasks with a non-cooperative attitude, and the alienated members could not participate, which in the end negatively affected the quality of interactions.

Thus, it is possible to think of a way to configure the group so that it consists only of three members in order for all members to participate as a modest alternative. However, instead of grouping students by simply excluding the alienated members, it may be necessary to place members in the central position, who play the role of creating a permissive atmosphere, where the alienated members can participate in all member activities and collaborative interactions, or to have teachers frequently inspect small-group activities and provide appropriate interventions and guidance.

Second, changes of types occurred in accordance with the leaders' central positions. If the leading member in the central position created an atmosphere where free communication was possible, all the members of the small group were involved in the interactions. However, when there was a member occupying the central position but who lacked the quality as a leader for the task resolution by collecting the opinions of members, he or she lost the central position to another member and the alienated members remained.

When all members were in equivalent positions without member in a central position, the number of alienated members tended to rise due to weak member cohesion. However, seeing that members took part in the interactions again at the end because of the equal positions of members confirmed that the alienation was not fixed but rather fluid as long as the members had a similar status among each other even if they were alienated in the interactions.

On the basis of this study, it is expected that future analyses will show how the type of interaction changes according to the level of inquiry or familiarity status with the inquiry topics. In addition, it is expected that studies about guidance and feedback of teachers and new students' participation in the interactions will follow.

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