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# Analysis of Collaborative Utterances among Elementary Students in Problem-Solving Process

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## Ⅰ. Introduction

Recently, collaborative competence has been emphasized in the education field and plenty of studies have been conducted (Maienschein, 1993; Norris-Tirrel, 2012; Partnership for 21st century skills, 2009; Wood & Gray, 1991). As the collaborative problem-solving domain was adopted in PISA 2015 (OECD, 2013), the initiative that focused on collaboration has been noticeable. In Korean education in the past, the aim of elementary mathematics education was students' high achievement, but the affective domain that includes collaboration is considered as an essential element now. In the Korea National Mathematics Curriculum in 2015, a collaborative attitude is presented clearly (Korea Ministry of Education, 2015).

Collaborative learning is a representative example that focuses on collaboration. Panitz(1999) suggested that collaborative learning is "a personal philosophy, not just a classroom technique"(p. 3), and students could participate in the learning process together while respecting and understanding each other's different competencies and situations. In many studies, students improve their achievement more effectively in collaboration than in individual learning, as well as in mathematics education (Johnson, Skon, & Johnson, 1980; Panitz, 1999; Slavin, 1980, 1991). Also, there are studies with conflicting conclusions on whether homogeneous groups or heterogeneous groups are more effective in collaborative learning (Baer, 2003; Hersberger, 1995; Webb, Nermer, Chizhik, & Sugrue, 1998). Recently, in addition to determining students' achievement in collaborative learning, studies about the collaboration process have been increased to analyze qualitatively how students collaborate with each other (Barron, 2000, 2003; Chiu, 2008). However, in Korea, there are few studies focusing on how collaboration develops during students' problem-solving. Therefore, in this research, three research questions were set to illuminate collaboration among students. First, how do collaborative utterances appear in the problem-solving process? Second, what influence do they have on the problem-solving process? Third, how does each group member participate in the collaborative utterances? While dealing with these three research questions, this research analyzed students' utterances through which they collaborate with each other, as well as how these utterances influenced the problem-solving process and how students participate in these utterances.

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## Ⅱ. Theoretical Framework

### 1. Collaborative interaction

The study of Piaget and Vygotsky promoted the academic interest in collaborative interaction. Piaget (2005) suggested that learners do learn through adaptation which consists of assimilation and accommodation; therefore, social experience could facilitate this intellectual growth. In contrast, Vygotsky (2009) suggested that language is the main tool which learners use, and learning could occur through social interaction. From these two main theories, numerous studies about students' interactions have been conducted (Erkens, 2004; Forman & Cazden, 1984; Stevens & Slavin, 1995; Summers & Volet, 2010; Webb, 1982, 1991).

Forman and Cazden (1984) suggested 3 types of interaction – parallel, associative, and collaborative interaction. Roschelle and Teasley (1995) concluded that "Collaboration is a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem"(p.70), and suggested Joint Problem Space (JPS) for "a shared conception of the problem"(p. 70). Collaborative interaction occurs in the process that constructs and maintains this JPS.

Chiu (2000) separated collaborative interaction more specifically according to the degree of collaboration and students' intellectual level and suggested 6 types of interaction. In All Locally Unknowing Persons groups, piecemeal guessing and joint construction interaction occurs. In Locally Unknowing Persons and Locally Knowing Persons groups, lecture and guided construction occurs. In all Locally Knowing Persons groups, accepted demonstration and automatic joint solution occurs. Kumpulainen and Kaartinen (2003) suggested the following 6 types of interaction: collaborative, tutoring, argumentative, conflict, domination, and confusion.

Regarding the interaction of students, Verba and Winnykamen (1992) showed that in groups of a high-achievement student and a low-achievement student, when the high-achievement student had a specialist status, they taught the low-achievement student in a substantial manner. In contrast, when a low-achievement student had a specialist status, collaborative interaction occurred in a reverse phenomenon where the high-achievement student took the teaching position again. This implied that when students whose achievement are heterogeneous interact, high-achievement students usually lead the interaction and low-achievement students develop their own learning strategies and cognition from the interaction. However, there are other studies that showed the quality of interaction was substandard in a homogeneous group of high-achievement students and that of low-achievement students, and in a heterogeneous group of high, middle, and low-achievement students (Dillenbourg, Baker, Blaye, & O'Malley, 1996; Webb, 1982). Mugny and Doise (1978) suggested that when students had different strategies, they had better results than when students had the same strategies. This revealed that the element of varying strategies was much more important than whether the groups are homogeneous or heterogeneous. In addition to the study showing positive learning results from low-achievement students' interaction (Schwar, Neuman, & Biezuner, 2000), if group members have different strategies, groups could produce positive learning results even when the groups are comprised of low-achievement students.

Many studies have focused on the process of collaboration among students. Dillenbourg et al. (1996) suggested that collaboration consists of negotiation and argumentation. Barron (2000) analyzed how collaboration appears during collaborative problem-solving and concluded that collaboration consists of 3 elements: shared task alignment, joint attention, and mutuality. Erkens (2004) suggested the collaborative elements as follows: focusing checking,

argumentation, and negotiation. Van Boxtel (2004) proposed the following four elements: talk about the concept to be learned, elaborative contribution from the participants, a continuous attempt to achieve a shared understanding of the concepts, and making productive use of the mediational means (tools) that are available.

All previous studies commonly posed that to collaborate, students in a group interaction should try to understand each other's perspective consistently to establish a common ground. Therefore, in this study, we defines collaboration as follows:

Collaboration is a consistent interaction among group members to establish their own common ground.

In this definition, the most important part is that group members should try to reach an agreement whenever they have any disagreements or conflicts in interaction. Hence, researchers identified utterances that facilitate and maintain collaboration, which are termed collaborative utterances that broaden the common ground in groups. Additionally, these collaborative utterances were observed during the group problem-solving process to analyze how group members collaborate.

2. Utterances analysis in interaction

Kumpulainen and Kaartinen (2003) used the utterances analysis frame below([Table 1]).

They analyzed students' utterances in interaction and determined how students develop collaborative interaction. Barron (2000) coded students' utterances as acceptances, clarifications, elaborations, rejections, and no response at all, then illustrated students' collaborative interactions. In this study, the utterances coding frame was constructed by revising previous studies' tools to include coding elements presented in both studies and to deal with students' utterances more sophisticatedly. The results are below([Table 2]).

[Table 1] Utterances analysis frame (Kumpulainen & Kaartinen, 2003)

| Category | Description |
|---|---|
| Informative | Provides information |
| Argumentative | Justifies information, opinions, or actions |
| Reasoning | Reasons in language |
| Evaluative | Evaluates work or action |
| Organizational | Organizes or controls behavior |
| Interrogative | Poses questions |
| Responsive | Replies to questions |
| Repetitive | Repeats spoken language |
| Agrees | Expresses agreement |
| Disagrees | Expresses disagreement |
| Dictation | Dictates text |
| Reading aloud | Reads text aloud |
| Affective | Expresses feelings and emotions |

[Table 2] Utterances coding frame

| Coding | Explanation |
|---|---|
| Information | Poses one's position and opinion |
| Question | Asks question for answers |
| Answer | Answers questions or action requests |
| Action request | Requests a particular action. |
| Repetition | Repeats former utterances |
| Agree | Expresses agreement to former utterances |
| Check | Checks former utterances |
| Rejection | Expresses disagreement to former utterances |
| Elaboration | Suggests additional explanations, evidence or refutes former utterances |
| Evaluation | Evaluates former utterances or other's action |
| Affective expression | Expresses emotions |

## Ⅲ. Methods

### 1. Participants

This study was conducted from Jan. 8th to Jan. 25th in 2018. The participants of this study were 5th -grade students in G elementary school located in Gangdong-district, Seoul, Korea. The study participation consent form and legal representatives consent form were given to students who had an interest in this study. Eventually, 12 students participated in this study. The students' groups were organized as below.

[Table 3] Group organization result

| Time \ Group | A (Mon, Wed) | B (Tue, Thu) |
|---|---|---|
| 9:30 ~ 10:30 | 4 students (Group 2) | . |
| 11:00 ~ 12:00 | 4 students (Group 3) | 4 students (Group 1) |

The mathematics achievement level of the 12 students was judged by 5th-grade mathematics evaluation results and homeroom teacher's opinion, shown below.

[Table 4] Group members' achievement level

| Group 1 | Achievement | Group 2 | Achievement | Group 3 | Achievement |
|---|---|---|---|---|---|
| Girl 1(A) | High | Girl 2(L) | High | Girl 1(P) | High |
| Girl 3(B) | Low | Boy 1(M) | High | Girl 2(Q) | Middle |
| Boy 1(C) | High | Girl 1(N) | Middle | Girl 3(R) | Middle |
| Girl 2(D) | Middle | Boy 2(O) | Basic | Girl 4(S) | High |

(*High:100~80% Middle:79~60% Low: 59~30% Basic: 29~0%)

Previous studies divided students into 3 groups (high, middle, low) when constructing heterogeneous groups (Kong & Shin, 2005; Lee & Park, 2004). In this study, students were also divided into 3 groups. Student O in group 2 had particularly low mathematics achievement, so this student's achievement was expressed as basic.

### 2. Data collection and analysis

For this study, a total 18 problems were selected by referring to the Korea national text-book and curriculum. In total, 31 recorded videos and voice recording were collected. From those, with the exception of some videos whose utterances coding was impossible due to machine faults, 15 videos were selected. Students' utterances from these videos were transcribed, coded and analyzed.

In the analysis process, all students' utterances were coded according to the utterances frame. A unit of a utterance could be determined by five elements: a final ending, a final intonation, a turn taking, a pause and a syntactic sufficiency (Kim, Cha, & Oh, 2011). In this study, it was determined by two elements: a final ending and a pause. Then, among the coded utterances, collaborative utterances were collected, and types of collaborative utterances were categorized. Two researchers coded independently, and inter-coder reliability (Cohen's $\kappa$) was 0.848($P$ =0.006). The two coders discussed disagreements about the coding results to retain coding reliability and validity.

## Ⅳ. Results

### 1. Collaborative utterances aspect

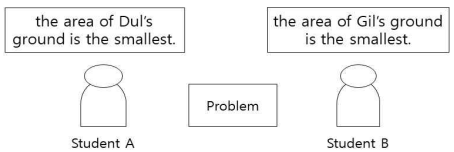
#### 1) Collaborative utterances

Shown below is the manner in which collaborative utterances were analyzed from the coding results of the 3 groups. The below conversation is a sample of the utterances when group 1 solved the 1st problem in the 1st session.

[Problem-solving scene 1] the 1st problem in the 1st session of Group 1

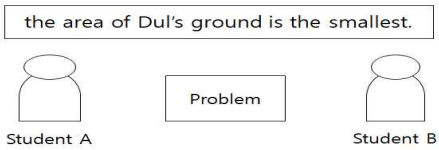
| | | | |
|---|---|---|---|
| 39 | A | : The area of the parallelogram ground is half of the area of square ground. | Information |
| 40 | B | : So Gil's ground area is the smallest one. | Elaboration |
| 41 | A | : Nope. | Rejection |
| 42 | | : Isn't Dul's ground area the smallest one? | Elaboration |
| 43 | B | : No. | Rejection |
| 44 | A | : Really? | Elaboration |
| 45 | B | : The area of Dul's ground is…. | Elaboration |
| 46 | A | : Oh, the area of Gil's ground is…. | Elaboration |
| 47 | B | : The smallest. | Elaboration |
| 48 | A | : Right. Then we have to change these two number. | Elaboration |
| 49 | | : Okay. | Agree |

In the 39th utterance, student A provided some information by reading the problem sentences. Then, student B spoke an elaboration utterance, which added some explanation to student A's utterance. In the 40th utterance, student B expressed the opinion of the person whose ground area is the smallest. Student A responded to this utterance and expressed her own opinion, "the area of Dul's ground is the smallest." through the 41st and 42nd utterances. This conversation flow could be expressed in a picture, shown below.




[Fig. 1] Before collaborative utterances

Until the 42nd utterance, student A and student B had different opinions. Their different opinions gradually became similar through the 43rd utterance to the 49th utterance. This consensus phenomenon could be expressed in a picture as below.




[Fig. 2] After collaborative utterances

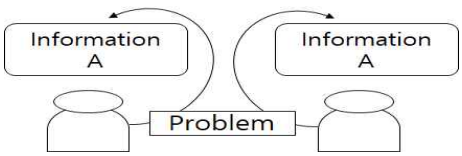
Initially, student A and student B had dissimilar positions to the problem conditions. However, in the end, they made an agreement that the area of Dul's ground is the smallest; those 11 utterances through which consensus was made were analyzed as collaborative utterances.

2) Types of collaborative utterances

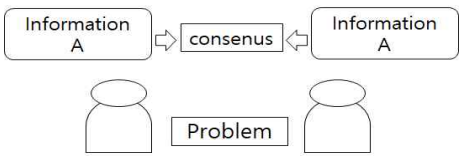
After analyzing how collaborative utterances appear, collaborative utterances were categorized in 2 types.

(1) Interchange type

Interchange type is divided into 2 processes: the verification process and the modification process. First, before the verification process, group members have individual opinions about problems. Through the verification process, group members recognize that they all have the same opinion. This process could be expressed in a picture as below.




[Fig. 3] Before verification process




[Fig. 4] Verification process

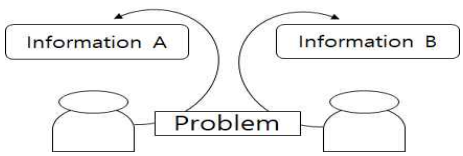
Through the verification process, group members could establish their own common ground since they already have the same information from the problem. The below conversation is an example of this verification process.

[Problem-solving scene 2] the 1st problem in the 1st session of Group 1

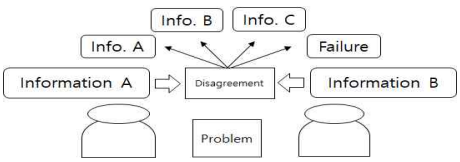
| | | | | |
|---|---|---|---|---|
| 25 | B | : | These 4 conditions gave us area information and the other condition gave us shape information. | Information |
| 26 | A | : | Right. | Agree |

In this conversation, student A and student B checked that they had the same opinion, and this implied that they had a common ground about the problem conditions.

Second, the modification process is different from the verification process because it occurs when group members have different opinions. Therefore, as a result of the modification process, group members could reach a consensus but also fail to find common ground. The modification process could be expressed in a picture as below.




[Fig. 5] Before modification process




[Fig. 6] Modification process

In interactions, group members recognized that they had different opinions on a problem's particular condition. They usually interchanged their opinions through elaboration utterances, and after the modification process, they might reach an agreement that A, B, or a new opinion (C) that was derived from the group interaction is correct. However, in some cases, they failed to make a consensus and could not establish common ground. Conversation examples are below.

[Problem-solving scene 3] 3rd problem in the 5th session of Group 1

| | | | | |
|---|---|---|---|---|
| 79 | A | : | 2 right triangles can make a rectangle. | Elaboration |
| 80 | | : | Then one side is 40cm. | Elaboration |
| 81 | | : | Hmm…, no. it's wrong | Evaluation |
| 82 | C | : | Here is 40, and here is 30, then here is 50. | Elaboration |
| 83 | | : | Then this part means 30cm in the whole 40cm? | Elaboration |
| 84 | | : | Then only 10cm left. | Elaboration |
| 85 | A | : | So here is 40. | Elaboration |
| 86 | | : | And here is 30. | Elaboration |
| 87 | C | : | No, only 10cm left. | Elaboration |
| 88 | A | : | Why? | Elaboration |
| 89 | | : | Oh, you're right. | Agree |
| 90 | C | : | So one side is 40cm. | Elaboration |
| 91 | A | : | Then this is wrong. | Evaluation |
| 92 | | : | This is wrong. | Evaluation |
| 93 | | : | Then what could be possible? | Evaluation |
| 94 | C | : | 8cm, 6cm, 8cm, oh…. | Elaboration |
| 95 | A | : | This cannot be possible. | Elaboration |
| 96 | C | : | Oh! then we can do this way. | Elaboration |
| 97 | | : | This is a right triangle of 10cm, 8cm, 6cm, so we can draw this way. | Elaboration |
| 98 | | : | And here we can draw 10cm, 6cm, 8cm. | Elaboration |
| 99 | A | : | This way? | Elaboration |
| 100 | C | : | Right. | Agree |

In the 94th and 95th utterances, student A and student C realized that their initial opinions were both wrong. Then, in the 96th and 97th utterances, student C presented a new opinion and student A accepted student C's opinion. They made a consensus through the modification process, so they maintained their problem solving-process.

There are 2 cases in which the group members cannot reach an agreement through the modification process. In the first case, group members have different opinions and cannot make a consensus

because they do not have enough mathematical evidence to reach a consensus. In the second case, group members cannot understand each other's opinion itself, so they don't modify their own opinion nor accept the other's opinion and eventually cannot reach an agreement. Conversation examples related to the first case are below.

[Problem-solving scene 4] 1st problem in the 1st session of Group 1

| | | | |
|---|---|---|---|
| 160 | A | : How could we get Chun's information? | Question |
| 161 | B | : Chun's ground shape is a square. | Answer |
| 162 | A | : Is Chun's ground shape a square? | Question |
| 163 | B | : Yes. | Answer |
| 164 | | : Because her ground is the biggest one. | Elaboration |
| 165 | | : It is exact that Chun's ground shape is a square. | Elaboration |
| 166 | A | : One side of parallelogram is, one side of square is…. | Elaboration |
| 167 | | : Then isn't a parallelogram bigger than this square? | Elaboration |
| 168 | B | : What? | Elaboration |
| 169 | | : Wait. | Action request |

In this conversation, both students could not understand the problem's conditions clearly. In the 167th utterance, student A suggested an opinion which was incompatible with student B's opinion. However, student B did not accept student A's opinion nor revise her own opinion. Student A also did not develop her own utterance. After the 169th utterance, they did not discuss about this issue any longer and dealt with other issues instead. This happened because two students could not understand the conditions of the problem clearly, so they could not produce enough proper mathematical evidence. Eventually, in this conversation, student A and B did not reach any consensus.

Also, even though the group members noticed that their opinions were different, they did not try to eliminate the intellectual gap and failed to find a common ground. Conversation examples related to this case are below.

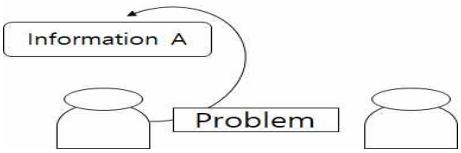
[Problem-solving scene 5] 1st problem in the 2nd session of Group 3

| | | | |
|---|---|---|---|
| 61 | P | : The smallest…. | Information |
| 62 | Q | : Can't we just say 3? | Information |
| 63 | | : I think 3 is the answer. | Elaboration |
| 64 | P | : 21. | Information |
| 65 | Q | : I just want to answer 3. | Information |
| 66 | P | : I just want to answer 21. | Information |
| 67 | Q | : No wait. | Action request |
| 68 | P | : My answer is 42. | Information |
| 69 | R | : Me, too! | Elaboration |
| 70 | P | : Why? | Elaboration |
| 71 | R | : This 1cm could be divided like this. | Elaboration |
| 72 | P | : But we don't know this is accurate. | Evaluation |
| 73 | Q | : Just answer 42! | Information |
| 74 | P | : 42! | Repetition |
| 75 | Q | : 42? | Question |

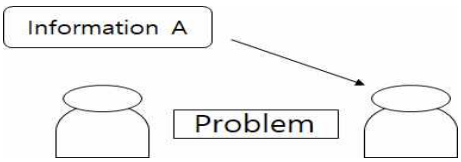
In this conversation, student P and student Q had dissimilar opinions. Student P answered 21 and later changed her answer to 42, and student Q answered 3. Although their answers were clearly different, they did not elaborate on their own opinion nor try to establish a common ground. In the 73rd utterance, student Q accepted student P's answer (42) without elaborating her answer and posed a question about it again in the 75th utterance, which makes it is hard to judge if they agreed that the answer was 42. Moreover, student P and student R had the same answer as 42, but student P did not agree with student R's 71st utterance. This implied that even though they had same answer, they did not try to reach an agreement about the reason that they selected the answer, and after the 75th utterance, they did not revisit this issue again. Therefore, it could be interpreted that they did not form a consensus about their answer.

(2) Deliver type

In deliver types, one group member unilaterally delivers his/her own opinion to the other group members.




[Fig. 7] Before deliver type




[Fig. 8] Deliver type

In deliver type, only one group member gains information from a problem then delivers it to other group members who do not have any information about the problem. Whereas the interchange type of collaborative utterances occurs after all group members have their own opinion about the problem, deliver type occurs only one group member has his/her opinion before others. Hence, other group members take a passive attitude by accepting the first member's opinion without elaborating on it. Conversation examples are below.

[Problem-solving scene 6] 2nd problem in the 5th session of Group 3

| | | | |
|---|---|---|---|
| 47 | P | : The proportion, the possibility is same. | Information |
| 48 | R | : Okay. | Agree |
| 49 | P | : Look. | Action Request |
| 50 | | : This has 2, and this has 4. | Information |
| 51 | | : Then four sixth and two sixth. | Elaboration |
| 52 | R | : Okay. | Agree |
| 53 | P | : Six twelfth and four twelfth. | Elaboration |
| 54 | R | : Okay. | Agree |
| 55 | P | : If we reduce these fractions…. | Elaboration |
| 56 | | : Then two sixth and four sixth. | Elaboration |
| 57 | R | : Okay. | Agree |
| 58 | P | : Then they are same. | Elaboration |
| 59 | R | : Okay. | Agree |
| 60 | P | : So the answer is two. | Elaboration |

In this conversation, student P already found the answer by herself, so she explained her problem-solving process to the other group members. When student P explained her solving process, student R listened to her passively without asking questions or elaborating on it. Through these utterances, student P delivered her opinion to student R to develop an agreement that her opinion is right, so these utterances could be analyzed as collaborative utterances. However, student P led the whole utterances dominantly, so these utterances are categorized as the deliver type.

2) The influence of collaborative utterances in the problem-solving process

[Table 5] The flow of 2nd problem in the 6th session of Group 3

| | |
|---|---|
| 1 | Agreement on average(4 sentences) |
| ↓ | |
| 2 | Agreement that 18 is impossible(6 sentences) |
| ↓ | |
| 3 | The pair (6,14) is possible and the least common multiple is 42(19). |
| ↓ | |
| 4 | The pair (4,1) is possible and the least common multiple is 16(10). |
| ↓ | |
| 5 | Re-agreement that the least common multiple of (6,14) is 42(5). |
| ↓ | |
| 6 | Agreement that the pair (2, 18) is also possible (3). |
| ↓(Teacher's help) | |
| 7 | Agreement about other possible pairs(11) |
| ↓ | |
| 8 | Agreement that the pairs (3,17), (7,13) are both possible(4). |
| ↓ | |
| 9 | Agreement on the problem's conditions(61) |
| ↓(Teacher's help) | |
| Problem solved | |

(* The numbers in parentheses indicate the numbers of sentences which constitute the agreement process)

Group 3 made an agreement in every collaborative utterance and all of the collaborative utterances are interchange type. In the solving process, the teacher helped them twice. At first, the teacher helped them notice that there were still more pairs because they concluded that they found all possible pairs and stopped looking for other pairs. Second, the teacher let them consider the condition of the problem that the two numbers of one pair have to be different so they could exclude the pair (10, 10). In this problem-solving process, the interchange type collaborative utterances occur dominantly, and through these utterances, the group members found a broad common ground. Although they encountered some impasse because they missed the problem's conditions or had some errors, when the teacher gave them a little help, they discovered the right way to solve the problem immediately. Likewise, there were 5 cases where the proportion of interchange types of collaborative utterances were highly dominant: the 1st problem in the 1st session, the 2nd problem in the 2nd session, the 3rd problem in the 5th session, and the 2nd and 3rd problems in the 6th session of Group 1.

Otherwise, it is notable that the proportion of agreement in collaborative utterances to whole collaborative utterances was considerably low in the 1st problem of the 2nd session of group 2. Additionally, they could not agree on how to solve the problem, even though the teacher helped them, and they finally failed to solve the problem. The flow of problem solving is shown below([Table 6]).

In this case, each group member recognized that their opinions were different, but they could not mediate their dissimilar opinions even through collaborative utterances. The teacher also gave them a clue that there were some errors in each member's explanation, but they could not apply this help to their problem-solving process. Thus, the group could not reach an agreement even though they participated in the interchange type of collaborative utterances, so they could not respond to the teacher's help as a group. The individual understanding about the teacher's help caused another disagreement among group members and eventually made them fail to produce the right answer.

[Table 6] The flow of 1st problem in the 2nd session of Group 2

| | |
|---|---|
| 1 | Agreement that the greatest common factor is 2(5 sentences). |
| ↓ | |
| 2 | Agreement that the GCF of 6 and 10 is 2(4 sentences). |
| ↓ | |
| 3 | Agreement about the least common multiple of 3 and 7(5) |
| ↓ | |
| 4 | Fail to have a common answer even though explaining each opinion(41) |
| ↓(Teacher help) | |
| 5 | Fail to have an agreement even though student M tried to explain(18) |
| ↓ | |
| 6 | Agreement that the answer is 2(5). |
| ↓ | |
| 7 | Agreement that it is possible to make a square using rectangles(7) |
| ↓ | |
| 8 | Fail to have an agreement about student M's problem solving process(7) |
| ↓ | |
| 9 | Fail to have an agreement about student L's problem solving process(9) |
| ↓(Teacher help) | |
| Failed to solve the problem | |

It is essential not only to have numerous collaborative utterances but also to reach an agreement to apply the teacher's help to the problem-solving process properly. Depending on the

agreement, group members can accept the teacher's help as a similar meaning, and this extends to another agreement which can facilitate their problem-solving process.

3) Participation of each group member in collaborative utterances

In this part, individual participation in each group will be analyzed. The problems presented in Table 7, 8, and 9 are dissimilar because each group performed differently in each session. For example, group 1 solved three problems in 6th session, so it could be possible to analyze students' utterances in all three problems. In contrast, group 2 and 3 could solve only two problems in 6th session, so data of third problem could not be collected in group 2 and 3. Furthermore, a few data were excluded, especially those of group 2 and 3, because the number of utterances which were irrelevant to the problem-solving exceeded 50% of the total. This is the reason of why each table presents different numbers of problems.

Individually counted utterances in each table were all coded according to the utterances coding frame(Table. 2) and were relevant to problem-solving process. Thus, the number of group members' utterances implies how substantially they contribute to the collaborative utterances in each problem-solving process.

Participation of each member of group 1 in every problem-solving process is shown below.

[Table 7] Participation of each group member of Group 1

| Problem | Individual utterances | | Utterance proportion(%) | Main type of collaborative utterances |
|---|---|---|---|---|
| 1st problem in 1st session | A : | 220 | 62.5 | Interchange |
| | B : | 152 | 37.5 | |
| 1st problem in 2nd session | A : | 36 | 43.9 | Interchange |
| | B : | 7 | 8.5 | |
| | C : | 33 | 40.2 | |
| | D : | 6 | 7.3 | |
| 2nd problem in 2nd session | A : | 76 | 35.5 | Interchange |
| | B : | 61 | 28.5 | |
| | C : | 69 | 32.2 | |
| | D : | 8 | 3.7 | |
| 2nd problem in 5th session | A : | 24 | 70.5 | Interchange |
| | B : | 4 | 11.7 | |
| | C : | 2 | 5.8 | |
| | D : | 4 | 11.7 | |
| 3rd problem in 5th session | A : | 253 | 50.8 | Interchange |
| | B : | 43 | 8.6 | |
| | C : | 189 | 37.9 | |
| | D : | 13 | 3.0 | |
| 1st problem in 6th session | A : | 3 | 50 | Interchange |
| | C : | 3 | 50 | |
| 2nd problem in 6th session | A : | 40 | 41.2 | Interchange |
| | C : | 44 | 45.3 | |
| | D : | 13 | 13.4 | |
| 3rd problem in 6th session | A : | 93 | 46.0 | Interchange |
| | C : | 84 | 41.5 | |
| | D : | 25 | 12,3 | |

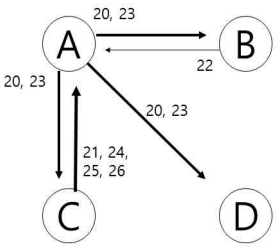
In group 1, the interchange type collaborative utterances were prominent. It is notable that the participation proportion of Student A and C is remarkably high. The cause of this proportion could be inferred from conversation examples as below.

[Problem solving scene 7] 1st problem in the 2nd session of Group 1

| | | | |
|---|---|---|---|
| 20 | A | : What exactly the greatest common factor is? | Question |
| 21 | C | : The greatest common factor…. | Answer |
| 22 | B | : I don't know anything. | Information |
| 23 | A | : Well, 30? | Information |
| 24 | C | : Not 30! | Rejection |
| 25 | | : It has to be much smaller. | Elaboration |
| 26 | | : Than 10 and 6. | Elaboration |

This conversation is a part of the 1st problem-solving process in the 2nd session of group 1. At first, student A asked a question to student B, C, and D, and only student C answered it. Student B

said that she did not have any idea, and student A suggested 30 as an answer without confidence, and only student C responded. This participation proportion could be expressed as [Fig. 9].



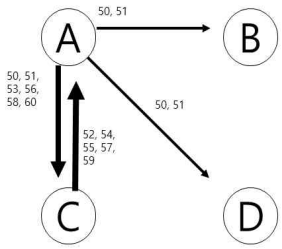

[Fig. 9] Individual collaborative utterances flow of Group 1 A

The first utterance of student A was towards three members so the arrow also pointed to all three members and the response of student B and C was expressed as an arrow pointing to student A. Student A had 2 utterances in this conversation, so the arrow of student A has the thickness of 2. Also, student B had 1 utterance, which has the thickness of 1, and student C, who had 4 utterances, has the thickness of 4.

Next, the conversation example and participation proportion of 2nd problem in the 5th session of group 1 are below.

[Problem-solving scene 8] 2nd problem in the 5th session of Group 1

| | | | |
|---|---|---|---|
| 50 | A | : Then it is 1600 $cm^2$. | Information |
| 51 | | : The area is 1600 $cm^2$. | Elaboration |
| 52 | C | : So the length of one side is 40 cm. | Elaboration |
| 53 | A | : The length of one side? | Repetition |
| 54 | C | : Yes. | Agree |
| 55 | | : 40 times 40 is 1600. | Elaboration |
| 56 | A | : 40…. | Repetition |
| 57 | C | : Times 40 is 1600. | Elaboration |
| 58 | A | : So is the one side of square 40? | Elaboration |
| 59 | C | : Yes. | Agree |
| 60 | A | : 40 times 40, then here is…. | Elaboration |

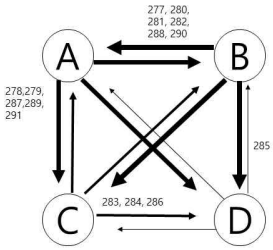



[Fig. 10] Individual collaborative utterances flow of Group 1 B

In this conversation, the first utterance of student A was toward three members, but only student C responded to it. Then, only student A and C participated in continuous utterances. In contrast, students B and D also participated actively in the 2nd problem-solving process in the 5th session.

[Problem-solving scene 9] 2nd problem in the 5th session of Group 1

| | | | |
|---|---|---|---|
| 277 | B | : We can fill this part. | Elaboration |
| 278 | A | : Then we need 2 here. | Elaboration |
| 279 | | : And did we need 4 here? | Elaboration |
| 280 | B | : Yes. | Agree |
| 281 | | : We need 2. | Elaboration |
| 282 | | : Well, it's right. | Evaluation |
| 283 | C | : Wait, no. | Rejection |
| 284 | | : Because here…. | Elaboration |
| 285 | D | : Well, this became a square. | Elaboration |
| 286 | C | : It is 8cm if we draw 4. | Elaboration |
| 287 | A | : Ha, isn't it 2cm? | Elaboration |
| 288 | B | : Right, 2cm. | Elaboration |
| 289 | A | : 2, 2, 2, 2. | Elaboration |
| 290 | B | : 2 times 4 is 8. | Elaboration |
| 291 | A | : Then how about drawing a rectangle? | Elaboration |




[Fig. 11] Individual collaborative utterances flow of Group 1 C

In this conversation example, all 4 students participated in the collaborative utterances. Likewise, depending on the situation, sometimes only students A and C participated in the discussion, or all 4 students participated in it together. Considering that students A and C have high achievement and the other 2 students have low achievement, this situation might be related to the variations in achievement. While all 4 students participated in collaborative utterances because they could all understand the meaning in the utterances, only 2 students participated because the other 2 students could not understand the meaning of the utterances.

In addition, participations of each member of group 2 in every problem-solving process were analyzed as [Table 8].

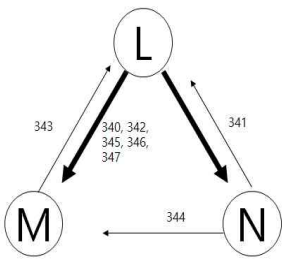
[Table 8] Participations of each group member of Group 2

| Problem | Individual utterances | | Utterance proportion(%) | Main type of collaborative utterances |
|---|---|---|---|---|
| 1st problem in 2nd session | L : | 45 | 44.5 | Interchange |
| | M : | 38 | 37.6 | |
| | N : | 18 | 17.8 | |
| 2nd problem in 6th session | L : | 36 | 69.2 | Deliver |
| | N : | 4 | 7.6 | |
| | O : | 12 | 23.0 | |

When students of group 2 solved the 1st problem in 2nd session, they hardly could build consensus. However, all students tried to participate in collaborative utterances, and the conversation example and participation proportion of the 1st problem in 2nd session are below.

[Problem-solving scene 10] 1st problem in the 2nd session of Group 2

| | | | |
|---|---|---|---|
| 340 | L | : The answer is 10.5! | Information |
| 341 | N | : 10.5? | Information |
| 342 | L | : It is 10.5! | Information |
| 343 | M | : Suddenly? | Evaluation |
| 344 | N | : But you said the answer was 1.5, before! | Information |
| 345 | L | : No. | Rejection |
| 346 | | : If supposed 21, 21, 2 here, we have to multiply this 10 times, then it becomes 20. | Elaboration |
| 347 | | : And we have to divide 2 by 1 to get 1. | Elaboration |
| 348 | | : So the answer is 10.5 and we are done. | Elaboration |




[Fig. 12] Individual collaborative utterances flow of Group 2

In this problem-solving process, although student L led the collaborative utterances, other two students also tried to participate in them. However, in the 2nd problem in 6th session, the main type of collaborative utterances was the deliver one, thus, student L dominated the collaborative utterances.

Participations of each member of group 3 in every problem-solving process are shown as [Table 9].

[Table 9] Participations of each group member of Group 3

| Problem | Individual utterances | | Utterance proportion(%) | Main type of collaborative utterances |
|---|---|---|---|---|
| 1st problem in 1st session | P : | 26 | 37.6 | Interchange |
| | Q : | 14 | 20.2 | |
| | R : | 24 | 34.7 | |
| | S : | 5 | 7.2 | |
| 1st problem in 2nd session | P : | 59 | 38.0 | Interchange |
| | Q : | 60 | 38.7 | |
| | R : | 23 | 14.8 | |
| | S : | 13 | 8.3 | |
| 2nd problem in 5th session | P : | 121 | 56.8 | Deliver |
| | Q : | 46 | 21.5 | |
| | R : | 45 | 21.1 | |
| | S : | 1 | 0.4 | |
| 1st problem in 6th session | P : | 40 | 58.8 | Deliver |
| | Q : | 15 | 22.0 | |
| | R : | 12 | 17.6 | |
| | S : | 1 | 1.4 | |
| 2nd problem in 6th session | P : | 60 | 49.1 | Interchange |
| | Q : | 26 | 21.3 | |
| | R : | 19 | 15.5 | |
| | S : | 17 | 13.9 | |

When the main type of collaborative utterances was the interchange one, even though high-achievement students led the collaborative utterances, all group members tried to participate in them. In contrast, one student almost controlled them when the main type of collaborative utterances was the deliver one.

Analyzing three groups' utterances, collaborative utterances were generated actively in group 1. The paramount difference between group 1 and other groups is the frequency of elaboration utterance. In group 1, the group members generated elaboration utterances more frequently after one member presented an opinion. Thus, group 1 could keep their arguments and reach consensus more easily than other groups.

## V. Conclusions

The purpose of this study is to analyze students' utterances through which they collaborate with each other, as well as how these utterances influenced the problem-solving process, and how students participate in these utterances. The conclusions of this study are as follow.

First, interchange type collaborative utterances led group members to participate in discussions actively and facilitated their arguments. In deliver type collaborative utterances, one student solves problems without discussion, and other students are deprived of an opportunity that they can understand a problem by themselves. Moreover, according to Langer-Osuna (2016), the opinions of students who take an active role in problem-solving process have an authority. While few students dominate the problem-solving process as authoritative members, others cannot help but taking a passive position and it becomes difficult for them to participate in the process and discuss with each other depending on their own understandings.

In contrast, numerous interchange type collaborative utterances mean that each group member has their own opinion and, while interchanging their opinion, they can come to an agreement that is effective in the problem-solving process. In this interchanging process, the participation of each member could increase and the active participation of each member is more meaningful than the passive participation in deliver type collaborative utterances, according to the perspective of Vygotsky (2009) on Zone of Proximal Development (ZPD). Students can express their mathematical understanding corresponding their actual development through participating in interchange type collaborative utterances and enter their ZPD by responding other group members' utterances. Through

prolific interchange type collaborative utterances, students can broaden their own domain of understanding. This also emphasizes the results of previous study that students' active participation in groups could promote each other's cognitive change (Fawcett, 2002).

Second, interchange type collaborative utterances have a positive impact on the problem-solving process, and due to this, properly written problems should be provided for each group. Students can solve problems that they cannot solve individually while developing agreements through collaborative utterances and responding to the teacher's help sensitively. In contrast, when the problem can be solved by at least one group member, deliver type collaborative utterances occur. Therefore, problems that are apposite to group members' achievement should be developed for interchange type collaborative utterances.

Lastly, groups should be composed of students whose achievement levels are similar because each student's participation proportion depends on individual achievement. In the case that the achievement difference among students is significant, low-achievement students cannot help in the process but participate passively because it is hard for them to understand the utterances of high-achievement students. Chiu (2000) also discovered that in interactions between two students, if one student can solve a problem while the other cannot, the student who can solve the problem participates in the interaction more actively. If low-achievement students participate passively, it results in little positive change in a cognitive aspect. To help them participate actively, it is necessary for them to be grouped with similar achieving students. Therefore, students should be divided into groups that consider their achievement, which can help them understand each other's utterances.

In conclusion, the researchers tried to step forward in collaborative problem-solving research by illuminating how students reach an consensus through collaborative utterances and apply them to their problem-solving process. In further research, it would be necessary to examine other aspects of collaborative utterances such as how students' achievement is changed after collaborative utterances or desirable ways in which teacher could help students to generate collaborative utterances. Furthermore, it would be worthwhile to examine the impact of collaborative utterances to students who rarely speak but mainly listen to others in problem-solving process. Finally, it would be crucial to detect how teachers' actions and utterances could influence students' collaborative utterances.

## References

Baer, J. (2003). Grouping and achievement in cooperative learning. *College Teaching 51*(4), 169-174.

Barron, B. (2000). Achieving coordination in collaborative problem-solving groups. *The Journal of the Learning Sciences 9*(4), 403-436.

Barron, B. (2003). When smart groups fail. *The Journal of the Learning Sciences 12*(3), 307-359.

Chiu, M. M. (2000). Group problem solving processes: Social interactions and individual actions. *Journal for the Theory of Social Behaviour 30*(1), 26-49.

Chiu, M. M. (2008). Flowing toward correct contributions during group problem solving: A statistical discourse analysis. *The Journal of the Learning Sciences 17*(3), 415-463.

Dillenbourg, P., Baker, M. J., Blaye, A. & O'Malley, C. (1996). The evolution of research on collaborative learning. In E. Spada & P. Reiman (Eds.), *Learning in humans and Machine: Towards*

*an interdisciplinary learning science* (pp. 189-211). Oxford: Elsevier.

Erkens, G. (2004). Dynamics of coordination in collaboration. In van der Linden J. & Renshaw P. (Eds.), *Dialogic learning* (pp. 191-216). Dordrecht: Springer.

Fawcett, L. M. (2002). The effect of peer collaboration on children's problem solving ability. Retrieved on August 20, 2017 from http://ro.ecu.edu.au/these_hons/921

Forman, E. A. & Cazden, C. B. (1985). Exploring Vygotskian perspectives in education: the cognitive value of peer interaction. In Wertsch, J. V. (Eds.), *Culture, communication and cognition: Vygotskian perspectives* (pp. 323-347). Cambridge: Cambridge University Press.

Hersberger, J. (1995). On my mind: cooperative groups can and often should be homogeneous. *Mathematics Teaching in the Middle School, 1*(6), 436-438.

Johnson, D. W., Skon, L. & Johnson, R. (1980). Effects of cooperative, competitive, and individualistic conditions on children's problem-solving performance. *American Educational Research Journal 17*(1), 83-93.

Kim, S. J., Cha, J. E. & Oh, J. H. (2011). Utterance factors and utterance type. *Korean Semantics, 36*, 91-118.

Kong, H. J. & Shin, H. K. (2005). An analysis of communication means in the elementary mathematical small group cooperative learning. *Journal of Korea Society of Mathematics Education 9*(2), 181-200.

Kumpulainen, K. & Kaartinen, S. (2003). The interpersonal dynamics of collaborative reasoning in peer interactive dyads. *The Journal of Experimental Education 71*(4), 333-370.

Langer-Osuna, J. M. (2016). The social construction of authority among peers and its implications for collaborative mathematics problem solving. *Mathematical Thinking and Learning 18*(2), 107-124.

Lee, M. H. & Park, Y. H. (2004). Analysis for the influence of cooperative learning in small-group on children's mathematics learning. *A: The Mathematical Education 43*(1), 51-74.

Maienschein, J. (1993). Why collaborate?. *Journal of the History of Biology 26*(2), 167-183.

Ministry of Education. (2015). *Mathematics curriculum.*. Ministry of Education Notice, No. 2015-74.

Mugny, G. & Doise, W. (1978). Socio-cognitive conflict and structure of individual and collective performances. E*uropean Journal of Social Psychology 8*(2), 181-192.

Norris-Tirrell, D. (2012). Introduction: Assessing multiple dimensions of collaboration. *Journal of Health and Human Services Administration 35*(1), 4-10.

OECD. (2013). *PISA 2015 draft collaborative problem solving framework*. Retrieved on May 2, 2016 from http://search.oecd.org/callsfortenders/Annex%20ID_PISA%202015%20Collaborative%20Problem%20Solving%20Framework%20.pdf

Panitz, T. (1999). *Collaborative versus cooperative learning: A comparison of the two concepts which will help us understand the underlying nature of interactive learning.* Retrieved on March 29, 2017 from https://eric.ed.gov/?id=ED448443

Partnership for 21st century skills. (2009). *P21 framework definition.* Retrieved on April 14, 2017 from http://www.p21.org/ storage/ documents/ P21_Framework_Definitions.pdf

Piaget, J. (2005). *Language and thought of the child: Selected works* (Vol 5). London: Routledge.

Roschelle, J. & Teasley, S. D. (1995). The construction of shared knowledge in collaborative problem solving. In O'Malley C. (Eds.), *Computer supported collaborative learning. NATO ASI*

*Series (Series F: Computer and Systems Sciences)*, (vol 128, pp. 69-97). Berlin, Heidelberg: Springer.

Schwarz, B. B., Neuman, Y. & Biezuner, S. (2000). Two wrongs may make a right. If they argue together!. *Cognition and Instruction 18*(4), 461-494.

Slavin, R. E. (1980). Cooperative learning. *Review of Educational Research 50*(2), 315-342.

Slavin, R. E. (1991). Cooperative learning and group contingencies. *Journal of Behavioral Education 1*(1), 105-115.

Stevens, R. J. & Slavin, R. E. (1995). The cooperative elementary school: Effects on students' achievement, attitudes, and social relations. *American Educational Research Journal 32*(2), 321-351.

Summers, M. & Volet, S. (2010). Group work does not necessarily equal collaborative learning: evidence from observations and self-reports. *European Journal of Psychology of Education 25*(4), 473-492.

Van Boxtel, C. (2004). Studying peer interaction from three perspectives. In van der Linden J., Renshaw P. (Eds), *Dialogic learning* (pp. 125-143). Dordrecht: Springer.

Verba, M. & Winnykamen, F. (1992). Expert-novice interactions: Influence of partner status. *European Journal of Psychology of Education 7*(1), 61.

Vygotsky, L. S. (2009). *Mind in society: The development of higher mental process.* (Translated by Jung, H. W.) Seoul: Hagisiseup. (original edition in 1978)

Webb, N. M. (1982). Student interaction and learning in small groups. *Review of Educational Research 52*(3), 421-445.

Webb, N. M., Nemer, K. M., Chizhik, A. W., & Sugrue, B. (1998). Equity issues in collaborative group assessment: Group composition and performance. *American Educational Research Journal 35*(4), 607-651.

Webb, N. M. (1991). Task-related verbal interaction and mathematics learning in small groups. *Journal for Research in Mathematics Education 22*(5), 366-389.

Wood, D. J. & Gray, B. (1991). Toward a comprehensive theory of collaboration. *The Journal of Applied Behavioral Science 27*(2), 139-162.

# 문제 해결 과정에서 나타나는 초등학생들의 협력적 발화 특성 분석

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This is a case study that defined collaborative utterances and analyzed how they appear in the problem-solving process when 5th-grade students solved problems in groups. As a result, collaborative utterances consist of an interchange type and a deliver type and the interchange type is comprised of two process: the verification process and the modification process. Also, in groups where interchange type collaborative utterances were generated actively and students could reach an agreement easily, students applied the teacher's help to their problem-solving process right after it was provided and could solve problems even though they had some mathematics errors. In interchange-type collaborative utterances, each student's participation varies with their individual achievement. In deliver-type collaborative utterances, students who solved problems by themselves participated dominantly. The conclusions of this paper are as follows. First, interchange-type collaborative utterances fostered students' active participation and accelerated students' arguments. Second, interchange-type collaborative utterances positively influenced the problem-solving process and it is necessary to provide problems that consider students' achievement in each group. Third, groups should be comprised of students whose individual achievements are similar because students' participation in collaborative utterances varies with their achievement.

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