MODESTUM EURASIA Journal of Mathematics, Science and Technology Education, 2021, 17(12), em2051
ISSN:1305-8223 (online)
OPEN ACCESS Research Paper https://doi.org/10.29333/ejmste/11415

A Case Study of Children's Interaction Types and Learning Motivation in Small Group Project-Based Learning Activities in a Mathematics Classroom

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Received 6 June 2021 ▪ Accepted 26 October 2021

Abstract
As collaborative problem-solving skills are increasing in importance, Project-Based Learning (PBL) is being implemented in various ways, but the results differ depending on the participants. This study shows that the results of PBL depend on student interaction type and learning motivation. The difference in the levels of interaction and learning motivation between two groups of students utilizing different discussion processes was qualitatively explored. The participants in this study consisted of 8 students in the 6th grade of elementary school, and the intervention was conducted over the course of 10 lessons. The group for which the leader arbitrarily resolved conflicts had a type of inactive interaction and the level of motivation for learning was outside of the acceptable range compared to the group that took part in a democratic discussion. As the project progressed, it changed to a type of inactive interaction. Thus, the results suggest that the roles of individuals in a group should be adjusted to account for to the characteristics of PBL and the structure of the task; furthermore, an inquiry into how learning motivation changes according to social interactions with others should be conducted.

Keywords: Project-Based Learning (PBL), interaction, learning motivation, ARCS, elementary math education

INTRODUCTION

As collaborative problem-solving is increasingly emphasized as a key skillset (OECD, 2017), research and interest in collaboration in mathematics education are rising. In other words, Project-Based Learning, which allows students to experience real-world-like problems and collaboratively experience problem-solving processes, is widely studied because it can provide opportunities for students to apply concepts acquired in mathematics subjects and promote their learning motivation (Evans et al., 2018; Holmes & Hwang, 2014; Meyer et al., 1997). Among other areas of mathematics, statistical content is like project-based learning in that it is mainly related to real life and that students are leading the way in exploring problems by applying statistical knowledge they have learned earlier. Furthermore, in several studies of statistical learning (Jones et al., 2000; Mackay & Oldford, 2000; Wild & Pancucci, 1999), the statistical process is presented as steps 4-5 of problem (or official questions), data collection, analysis, interpretation, and conclusion. This can be understood in a similar context to the project-based learning process of topics, planning, practices, presentation, and evaluation. In other words, the 'topics' in the project-based learning process is the 'problem' in the statistical process; the 'planning and practices' in the project-based learning process are steps of 'data collection, analysis, and interpretation' in the statistical process; and the 'presentation and evaluation' in the project-based learning process is the 'conclusion' part of the statistical process.

However, it is necessary to clarify the achievements of PBL, as the results differ depending on participation levels. Blumenfeld and colleagues (1991) proposed that it is necessary to design project assignments by considering student interactions and motivations to increase student participation. In other words, the effort to understand student interaction and motivation is a prerequisite for successful PBL learning. Therefore, this study focused on the degree of student interaction and participation in a PBL task and attempted to define the

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Contribution to the literature

- This study analyzed students' interaction types and learning motivation levels in a PBL activity through a qualitative case study and explored the relationship between the two.
- The math-based project assignments in this study involve situations that may actually be experienced by the students in everyday life.
- The result of this study show that it can be inferred that the interaction type and the learning motivation level cyclically influence one another in a PBL environment.

pedagogical implications of motivation, which is the will of the students to participate.

Interaction is a type of two-way communication between two or more people and occurs when they influence each other (Anderson et al., 2001; Brophy, 1999; Jucks et al., 2003). When collaboratively solving problems in PBL, interaction takes place during the discussion process. Analyzing the small-group interactions that occur at this time in terms of structure or role, group cohesion, and group size helps to better understand the characteristics of the group and improve the group's functioning (Baker et al., 1987). The researchers (Baker et al., 1987; Kang, 2000; Kim, 2014; Kim & Kim, 2015; Shaw, 1976; Yoo, 2004, 2014) who first defined this type of interaction saw that understanding the direction and path of messages within the group allowed them to grasp the structure of communication that takes place during an interaction. Briefly, the common characteristics of previous studies can be classified according to (1) the degree of mutual exchange between members and (2) the number of students who participated in problem-solving. In other words, the form of communication is classified according to whether mutual exchanges between members are all connected vs. partially incomplete, and whether all group members participate in solving the problem together vs. some students are alienated.

Regarding mutual exchange among members, Shaw (1981) classified the types of communication network into the following categories: wheel, chain, Y, and circle patterns. Twenty-two possible cases were identified according to group size (3, 4, or 5) and the direction of exchange. Baker and colleagues (1987) also described the possible types of communication networks as 'all-channel network,' 'circle network,' 'wheel network,' and 'chain network,' and illustrated the trends in conversational direction. These studies attempted to clarify the relationships between group members by focusing on the direction of communication among members and showed that the structure of the conversation differs depending on the presence and identity of a single leader under the premise that all students are involved in the problem-solving process.

On the other hand, some studies (Kang, 2000; Yoo, 2014) developed categories based on the number of students who participated in the problem-solving process and the presence or absence of active problem-solvers, with a focus not only on the direction of communication, but also on who played a leading role in problem-solving, who contributed to problem-solving, and who did not participate. Therefore, the classifications included 'one-person-led,' 'partly participating,' and 'multi-participating' (Kang, 2000); 'monopolist' type and 'co-ownership' type (Kang, 2000; Yoo, 2014); 'distributed,' 'centralized,' 'centralized II,' and 'net type' (Kim, 2014); or alienation types and participant types (Kim & Kim, 2015). Notably, in Kim (2014), and Kim and Kim (2015), unlike the other studies, members who did not participate in the interaction were classified as a separate type of participant.

The level of participation of the group members is determined by the will and effort to solve the task, which can be described as 'motivation.' Motivation has been studied in various fields, including education, over a long period of time, and its definition varies. However, generally, motivation suggests the direction of action and an affective characteristic that sustains action (Keller, 2010; Shunk et al., 2008). In addition, it is difficult to describe as a single concept because factors including environment, culture, and personal characteristics shape motivation in a complex manner (Keller, 2010). Furthermore, motivation is often considered to be a personal issue; that is, it may be thought of as an individual learner's preliminary readiness for learning or a kind of personal feeling during and after learning. It is also thought to be difficult to change because it is formed over a long period of time (Keller & Song, 1999). Therefore, to study motivation, it is necessary to first consider the appropriate definition of motivation and develop a way to measure it. Since the ultimate purpose of this study is to improve learning motivation in PBL, we followed J. M. Keller's theory.

Keller (2010) argues that learning motivation should be designed in consideration of the educational process in terms of four factors: **A**ttention, **R**elevance, **C**onfidence, and **S**atisfaction. '**A**ttention' concerns the induction and maintenance of the student's concentration. '**R**elevance' is related to goals and values through a desired outcome, an idea, a feeling or a perception of being attracted to others. '**C**onfidence' is the perception of self-anticipation or control, and '**S**atisfaction' is related to having positive feelings about the learning experience.

Table 1. The information of the research participants

Student			Experience in PBL		Motivation for learning math before this project.		
Group		Gender	Other subjects	Math	About Math	Interesting subjects	The reason why I study math.
A	*S1	M	O	X	Interested	Math, Science	Pleasure, fun
	S2	F	O	X	Interested	Math, Science	Pleasure, interesting
	S3	M	O	X	Not interested	Physical education, art, computer	Forced by parents
	S4	F	O	X	Not interested	Korean, Discussion	For good grades in math
B	S5	M	O	X	Not interested	Physical education	Forced by parents
	S6	F	O	X	Not interested	Korean, Society	For good grades in math
	S7	F	O	X	Not interested	Art	Forced by parents
	S8	M	O	X	Interested	Math, Science	Pleasure, interesting (*Students belonging to the Math Gifted Class of the Regional Office of Education)

**S1; Student 1*

Studies on interaction and learning motivation (Bong et al., 2011; Kang et al., 2009; Min, 2015; Sim & Song, 2014) often rely on quantitative data. Since learning motivation is commonly measured through self-reported questionnaires given before and after a program or intervention, another type of measurement tool is required which allows researchers to observe motivation in depth by observing the change in a participant's emotions during and after an activity. Therefore, this study analyzed students' interaction types and levels of learning motivation in a PBL activity through a qualitative case study and explored the relationship between the two.

The research questions are as follows.

What types of interactions are seen in small group activities in Project-Based Learning (PBL)?

What were the students' motivations for learning in PBL?

What is the relationship between the types of interactions and learning motivations in PBL?

METHODOLOGY

Participants

Since this study aimed to extract individual cases and explore the relationship between them, participants were sampled according to the criteria of a qualitative case study. This is because it is essential to select cases that meet the purpose of the study through intentional sampling (Merriam, 1998). The sample selection criteria were as follows. First, to extract various cases of interest with different motivations for studying mathematics, a preliminary survey (interest in mathematics subject, subject he/she is interested in, and reason for studying mathematics) was conducted to assess mathematics learning motivation. Second, only students who had never been exposed to PBL in the mathematics classroom were selected so that PBL exposure itself would not become an additional variable. Third, the groups were matched by gender.

The study participants consisted of eight 6th grade students in a public elementary school in Seoul, Korea, 4 male students and 4 female students. Like the actual classroom environment, the groups were not divided according to learning motivation; instead, 2 male students and 2 female students were randomly assigned to each group. The specific characteristics of each student are shown in Table 1.

Procedure

For this study, a project was developed based on the mathematical concept of 'Data and Possibility' in consideration of the PBL class design stage of Intel Innovation for Education (2013). In addition, to ensure the validity of the project-based instructional design, consultation and review was conducted by two elementary mathematics education experts, a doctor and a doctoral student, and the lesson plan was modified and supplemented through preliminary research.

The PBL process was designed to emphasize the basic statistical processes used in elementary mathematics: problem and collection, organization and representation, analysis and interpretation, and presentation and evaluation. In addition, each stage consists of a lecture-style class given by a researcher, a task that confirms the statistical concept, and a process of actual project execution. Given the nature of the subject, if a student does not understand a previous concept or principle, the student may have trouble learning higher-level concepts or related concepts. Therefore, we aimed to make the practical project run smoothly by presenting and solving the statistical concept confirmation task after the lecture-style class.

The statistical concept confirmation stage consists of a problem that is related to the core concept. It is a more structured task than the project task; examples include selecting an appropriate sample target, completing a graph, and finding errors in data interpretation. This stage can be solved by applying concepts, principles, etc., or through a convergent solution within a limited

<The main project>

Our world can be read in numbers!

- What do we represent in statistics and what can we change? -

We are reporters who investigate, draw attention to, or suggest ways to solve problems and situations that we see around us. You should investigate the problem, analyze the data, and present the problem and your solution to the morning broadcast. Let us make a broadcast based on statistical data.

Figure 1. Summary of main project

range. In contrast, project assignments do not have a set solution, often involve conditions that are less clear, and have contextualized characteristics that may be encountered in everyday life. The project assignments in this study involve situations that may be experienced by the students in everyday life. The contents of the project assignments are summarized as shown in Figure 1.

The PBL process was conducted for a total of 10 lessons, 2 hours per lesson, after school, and individual interviews were conducted at the end of each stage, including a pre-interview before the PBL stage. Before and after the PBL intervention, questionnaire-type synchronous tests, the IMMS (Instructional Material Motivation Survey) and CIS (Course Interest Survey), were administered. To evaluate the PBL intervention, the achievement level and cooperation process in the data and possibility areas were analyzed with reference to the statistical thinking analysis frame (Kim & Kim, 2011). Based on the results, the performance and achievement level of the two teams were compared. Before solving the research problem, the characteristics of each group were examined, and it was confirmed that there was a difference in the process through which each group reached a consensus to solve the problem. Group A students exchanged opinions freely, listened to others' thoughts, and debated the most reasonable solution. Students who presented the wrong answer were not criticized by their classmates. Overall, they created a permissive atmosphere that allowed them to learn new things. In contrast, Group B determined the answer on the basis of arbitrary decisions made by the lead student. The rest of the members were worried that they would say something incorrect, so they could not easily express their opinions. Even though the lead student gave the wrong answer and one of the other members gave the correct answer, the group's solution was determined by the leader's incorrect answer.

Interaction and learning motivation were analyzed for research questions 1 & 2; then, the results of research questions 1 & 2 were synthesized for research question 3. The research process is shown in Figure 2.

Data Collection

The collected data included 10-hour videos of the problem-solving process, individual student interview data, individual and group activity sheets for each stage of PBL, and individual reflection journals. The entire problem-solving process was recorded, and transcribed, and individual interviews were conducted, recorded, and transcribed after each stage of the PBL process. Individual interviews were conducted a total of 5 times, including pre-interviews; each interview consisted of a semi-structured questionnaire and a loosely structured free-form component. Individual activity sheets prepared during student activity, group activity sheets determined through group discussions, and individual reflection journals created after the activity were collected.

Analysis

A qualitative case study was conducted by synthesizing the collected data. Qualitative data analysis was conducted in accordance with the six-step 'comprehensive analysis procedure' of Kim and Jeong (2017) (see Figure 3).

First, in the 'reading and organizing of data' phase, the collected data was repeatedly read to find its inherent meaning, and individual and group activities were classified into PBL learning stages. Second, in the 'analytical notes' phase, the trend was identified through intuition and insight on the flow of student interaction and learning motivation factors. Third, in the 'coding 1' phase, the case was divided according to speech type (task-related, task-independent, and operation-related) as the initial process of categorization, and further subdivided into three levels (too high, acceptable, and too low) by ARCS motivation factor. Fourth, in the 'coding 2' phase, to analyze the interaction type, students' speech direction and gaze, the temporal relationship between all students during the conversation related to problem-solving, the duration of the conversation, and the conversation frequency were analyzed in detail. In addition, learning motivation was subdivided into five levels (too high, too high/acceptable, acceptable, acceptable/too low, and too low). Fifth, in the 'coding 3' phase, patterns of interaction were derived, and the cases of each pattern were rearranged. In addition, an intra-case analysis by learning motivation factor and an analysis between the two groups were conducted. Sixth, the research results were visually arranged for clarity.

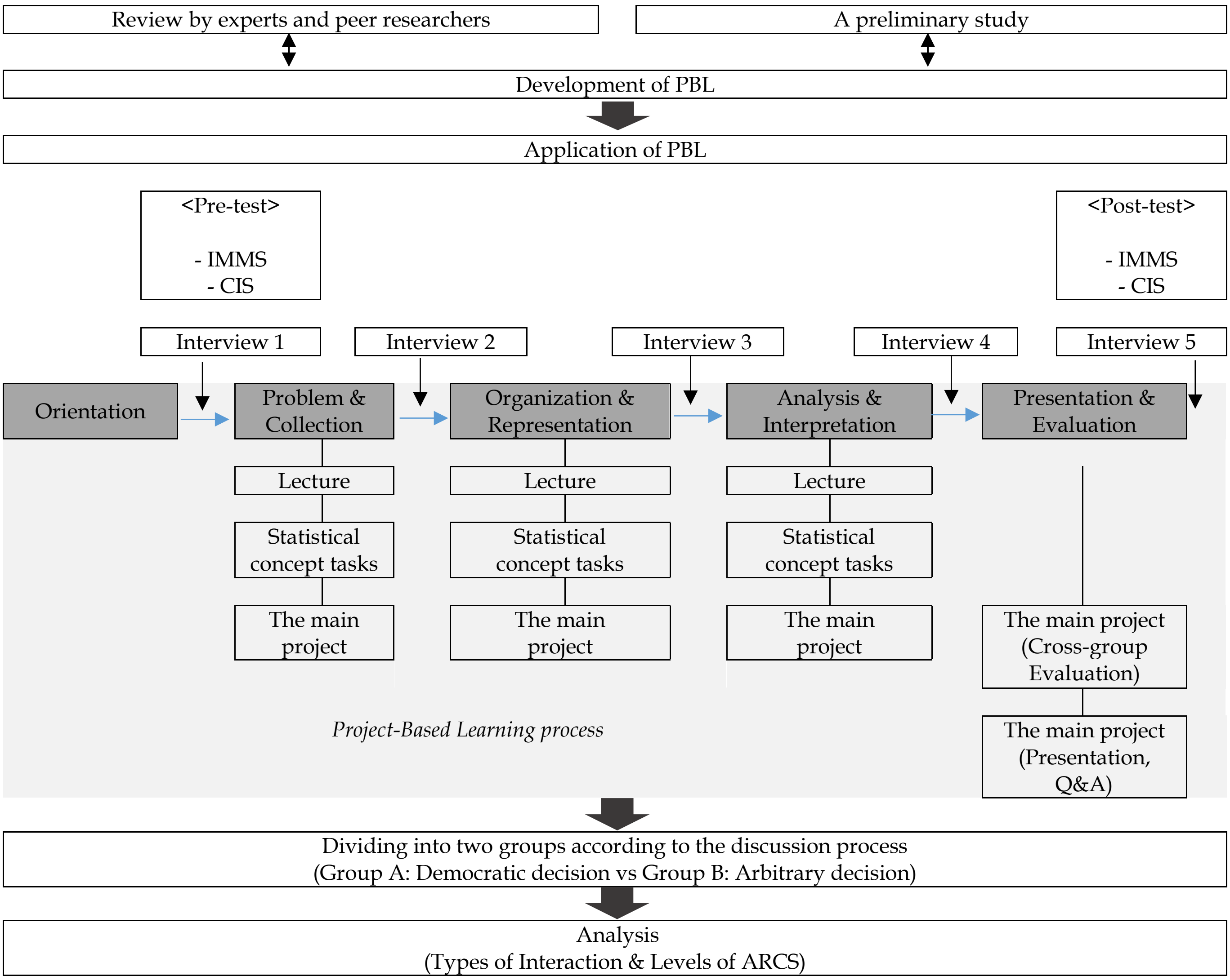
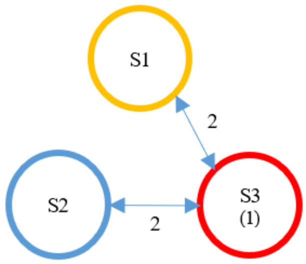


Figure 2. Procedures

Sequence	Contents
Reading and organizing data	■ Recorded Transcription/Organization
Analytical Notes	■ Intuitive analysis of the flow of interactions. ■ Analysis by ARCS motivational factors based on intuition and insights
Coding 1	■ Interaction Analysis: Separating Conversation Types ■ ARCS motivational factors analysis and case collection: 3 levels
Coding 2	■ Interaction analysis: direction, gaze, frequency, and conversation interval for problem-related conversations ■ Analysis of ARCS by motivational factors: 5 levels
Coding 3	■ Analysis of interaction patterns ■ Analysis of the pattern of changes by ARCS motivation factor ■ Case analysis, case-to-case analysis
Representing research results	■ Representation of results in tables, figures, graphs, etc.

Figure 3. Sequence of coding

Table 2. Sample dialogue analysis

Transcripts of the conversation	Direction		Structure of interaction
S1: No, (Looking at the work sheets) the newspaper called.	S1→S3	1 time	
S3: (Looking at the work sheets) Yeah, so the newspaper called.	S3→S1		
S1: // (Looking at S3) No, the newspaper answered the phone.	One way→S3		
S2: (Looking at S3) Yeah, they answered the phone	S2→S3	1 time	
S3: (Looks at the worksheet in silence for a while, and then looks at S2 again) What do you mean?	S3→S2		
S1: (Looking at S3) I mean, the voter called the paper and said, "I'm going to vote for this guy," and hung up.	S1→S3	1 time	
S3: (She looks at S2 and S1 one after another.) So, they did?	S3→S1 ↘S2	1 time	(): Total number of remarks made to all members and no one in particular.
S2: (Looking at S3) Yeah.	S2→S3		

Note. 'S1' means student 1; '//' means interrupting; '(…)' means student's action, gaze direction, and facial expression.

Table 3. Questioning protocol from the semi-structured interview

Attention
1) Draw a graph of your concentration during this class (additional questions about why you did so in the curve section).
2) When the class/task/content caught your attention and interest, what was it? If not, why do you think so?
3) Have you ever wanted to learn something more? When did you do that?
4) Have you ever been completely absorbed in class enough to forget the time? When did you do that?
Relevance
1) Why did you apply for this class?
2) If you were preoccupied with solving a task, why? (e.g., because the assignment was fun, to win the competition, etc.)
3) What value or meaning does this class have for you? Why do you think so?
Confidence
1) Do you think your project was a success/failure today? Why do you think so?
2) Do you expect to succeed in the remaining activities? Why do you think so?
Satisfaction
1) How did you feel during or after the activity? (Feeling accomplished, ashamed, etc.)
2) Do you think the compensation you received after class affected your motivation? Do you think there would have been a change in motivation if you hadn't been rewarded?
3) Do you think the evaluation was fair in this class? Do you think this is relevant to motivation?

To ensure the validity and reliability of the study, a review process with redundant coding and without consultation with fellow researchers as well as a revision process involving discussions about inconsistent results were conducted.

Interactions

Regarding the interaction type, only 'problem-solving' speech was analyzed by referring to Shaw's (1976) communication network and the studies of Kim (2014), and Yoo (2004), who patterned the relationship between participants in learning dialogue. In these studies, the pattern was defined in consideration of the amount and direction of the members' utterances. In this study, the same method was used, but to understand the direction of each interaction, we paid attention to who the student looked at and began speaking to. This is because who one is looking at while speaking is an important factor in analyzing the patterns and frequency of interactions. Therefore, in this process, the direction of gaze was recorded when transcribing the activity by referring to the recorded activity. This references the research of Lee and Kim (2001), who devised a framework for analyzing the direction of speech based on the division and gaze of speech, direction and distance, and external factors of speech. An example of dialogue analysis is shown in Table 2.

Motivation

Learning motivation was analyzed before and after the PBL process using the learning motivation test papers, interview and activity observations, and reflection journals.

The learning motivation test was taken from Min (2015). It consisted of a Korean version of Keller's (2010) IMMS (Instructional Material Motivation Survey) and CIS (Course Interest Survey) that was previously validated in Korea (Cronbach α = 0.89). The purpose of the test is to assess if there is any significant change in self-perceived learning motivation after completion of the project-based math class.

Interview data from the semi-structured questionnaire, loosely structured free-form discourse, and activity performance attitude observation data were coded and analyzed using the ARCS analytical

Table 4. Analysis framework: Case of relevance factor

Motivation levels	Analytical standards	Analytical contents and examples of coding
Too low level (TL)	They do not think math or homework is necessary. Or they know that they need math or assignments, but they think they have nothing to do with their lives. They study math because of other people's opinions or by force. For them, math is not related to themselves and is not an activity that must be accomplished.	(Student 7's interview) Teacher: Why did you apply for this activity? Student 7: It is just... I just wanted to help you. There's time. Teacher: You applied without knowing it was a math class. How did you feel when you found out it was math? Student 7: It was a little bit. I do not really like math. Teacher: Why do you think you're studying math? Student 7: My mom made me do it. I like physical education and art. I will not do math if it's not related to my dreams.
Acceptable /Too low level (ATL)	They believe that a task (or mathematical concept) is related to real life or to themselves. However, when they actually perform their tasks, they do not fulfill their duties or work hard.	(Student 5's case) He says he knows through "Dr. John Snow's Story" that mathematics is essential in real life, but he doesn't know why he should participate in actual project activities. And he was passive in the project.
Acceptable level (AC)	They think math subjects or tasks are relevant to real life or themselves and their interests.	Teacher: Why did you apply for activities? Student 8: I am interested in math, and I think I will be able to learn it well. Even though it's difficult, if you keep thinking about it, you'll feel a sense of accomplishment if the problem is solved.
Too high /Acceptable level (ATH)	They believe that projects (or mathematics) are closely related to real life or to themselves. However, they think they should study math to win against success or competition.	(Example of Student 6) She noted that this class helped her learn that math was related to real life and was very interesting. However, when participating in the project, she was too worried about falling behind in the competition and overly concerned about what the other teams were doing.
Too high level (TH)	Project work is no longer meaningful to them. They study because they are afraid of getting lower scores than others. Also, they think they should do better than others. They can't solve the problem properly because they have a lot of pressure and stress to succeed.	(Student 4's interview) I don't like math. I like competition. Honestly, I think competition is important. Everyone else did well, but I get angry if I don't do well. I don't want to do it anymore. I am completely discouraged. (omitted) To be honest... College entrance exam... It is more important than fun math games or activities now. If I want to get a well-paid job, I need to be good at math. So, I'm actually worried about middle school math... (omitted) I think I should stand out the most among the team members.

framework. Questioning protocols (see Table 3) and frameworks included contents and standards for each motivation factor (attention, relevance, confidence, and satisfaction). We recorded and repeatedly read interviews based on this question protocol and cross-analyzed with fellow researchers on what level the response was based on the analytical framework. This analytical framework is divided into the following levels: too high, too high/acceptable, acceptable, acceptable/too low, and too low. Here, too high/acceptable, or acceptable/too low indicates a case in which a student's performance changed quickly as the conditions changed. Therefore, the student's level of performance was generally not adequate, but was within the acceptable range at times. Some examples of relevance analysis among ARCS motivation factors are shown in Table 4.

Along with the example of a semi-structural interview of student 4, the 'relevance' graph of student 4 based on the analysis frame is as follows.

> Researcher: When did you focus most on your activities?
>
> S4-A: What if you find out the camera is filming? (laughs)
>
> *S4-A: Student 4, Group A
>
> Researcher: I see. Why do you think so?
>
> S4-A: I like competition (TH) Honestly, I think there are a lot of things like that. First, I must excel. (TH). Everyone else did well, but I don't think I did very well. So, they tend to get angry or do things like that if they seem to have done better. (laughs)
>
> Researcher: Ah... All right, competition... Do you think that's gonna work out better?
>
> S4-A: Yes. I think that's when I get more immersed. (TH)
>
> Researcher: Do you think this is closely related to life?

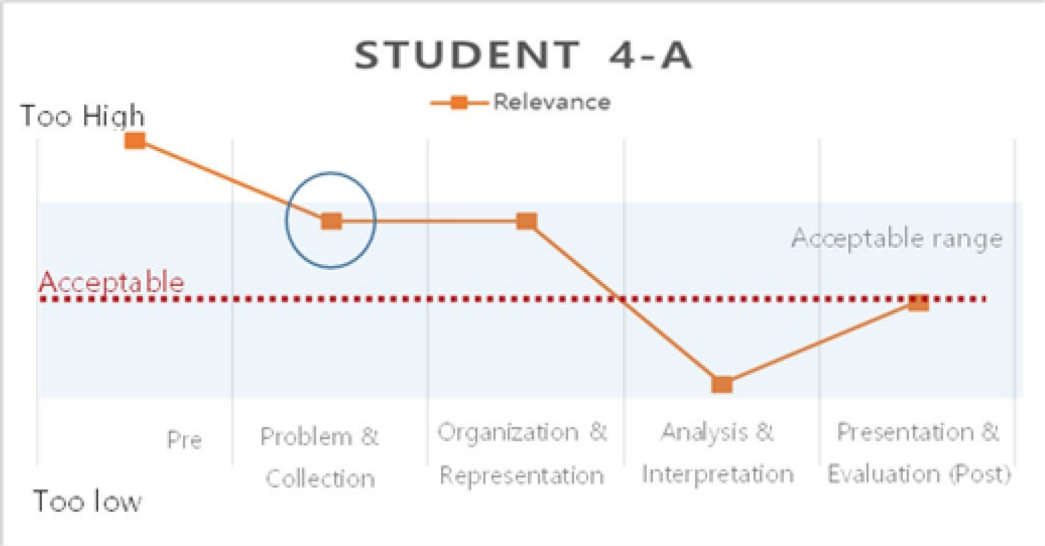


Figure 4. Relevance graph for Student 4

> No, I don't know why school mathematics is related (ATL). I mean... For example, when I learn ratio in school, it is not worthwhile for people to find ratio in class. But our projects can be interpreted and used in our daily lives. (AC)
>
> <Part of Student 4-group Interview: After the Problem & collection>

S4-A is not interested in math itself, but he said he had to study because he had to do better than others. There was therefore a 'Too high level' of relevance. However, he was interested in this project during the problem and collection phase and thought it was a valuable project. Therefore, it was marked as a 'Too high /acceptable level' of relevance (Figure 4, *Blue circle*).

RESULTS

Interactions

Types of interaction

Our data on students in a PBL activity on the elementary mathematics concept of 'data and possibilities' identified the following seven types of interaction: the 'even type,' 'central type I' (all exchanges), 'central type II' (partial exchanges), 'central type III' (straight exchanges), 'isolated type I' (partial exchanges), 'isolated type II' (straight exchanges), and 'isolated type III' (minimal exchanges). The types differ according to the degree of mutual exchange and the number of participating students. Mutual exchange is divided into a complete form and an incomplete form. More equal levels of participation are associated with more active interactions between members.

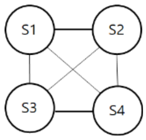
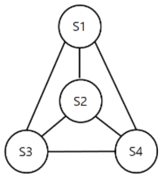
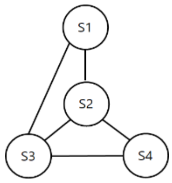
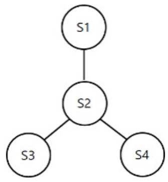
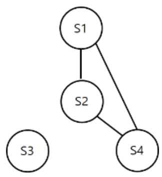
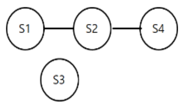
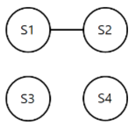
The 'even type' refers to equal participation, in which there is no specific leader, and everyone participates. The 'central type' has a problem-solving leader and is split into three subtypes according to the type of connection between participants. In the 'isolated type,' some members do not participate in the problem-solving process; this type is also divided into three subtypes according to the type of connection between participants. Details of each interaction type are shown in Table 5.

Group A vs. Group B

The types of interaction that appeared in the two groups differed depending on the characteristics of the PBL process and the degree to which the task was structured. First, the characteristics of the PBL process are as follows. When comparing the stages of the PBL process, the two groups showed the most active types of interaction when solving project tasks in the 'problem and collection' stage. It seems that member participation was comparatively easy in this stage because it required less knowledge of mathematical concepts and allowed for relatively free discussions on topics such as "what the subject should be."

When examining the difference between the stages of the statistical concept tasks and the main project, Group A and Group B showed different patterns. In the case of Group A, at the stage of statistical concept tasks, each student had to solve the problem first and then go through a discussion process without being given a specific role to determine the group's answer. This group showed 'even type' and 'central type I' interactions. However, during the main project stage, the 'central type I' and 'central type II' types emerged, as the problem was solved through the division of roles centered on a leader. In other words, the role of each member changed according to the task, and the student's situation and abilities were considered when that student took on a role, so active interactions occurred and all members participated in the process.

Table 5. Interaction types derived from PBL

Exchange	Participants	Types		Figures		Characteristics
Complete	All	Even			Active Interaction	Without a particular leader, all members interact, and discussion is actively carried out. The extent of member participation in solving the problem is the highest.
Incomplete		Central types	Central I (All exchanges)		↑	Discussions are centered around student S2, but all members are participating. This is like 'even type,' but has a leader and is leader-centered.
	Part		Central II (Partial exchanges)			Members interact around student S2, and there are exchanges between other members. This is like 'central I,' but some students do not directly interact.
			Central III (Linear exchanges)			Members interact around student S2 such that all non-central members interact only with the leader and are disconnected from each other.
		Isolated types	Isolated I (Partial exchanges)			Only students S1, S2, and S4 participate; S3 is left out of the discussion. In this interaction type, students S1 and S2 mainly lead and S4 supports them.
			Isolated II (Linear exchanges)		↓	Three out of four members exchange information around student S2, and opinions are delivered only through leader S2. S1 and S4 do not interact with each other. S3 is left out of the discussion.
			Isolates III (Minimum exchanges)		Inactive Interaction	Only S1 and S2 interact, while the other two students are excluded. The extent of member participation is the lowest because only part of the group is involved in solving the problem.

On the other hand, Group B, in which the students solved the problem without much discussion mainly through decisions arbitrarily made by the leader, showed the greatest degree of participation at the stage of statistical concept tasks or solved the problem on the basis of the leader's decisions alone. No other roles were assigned. Therefore, the members who were not confident in their mathematics abilities became bystanders in the problem-solving process, and only the leaders solved problems. However, in the main project stage, each student was given a certain role to play, resulting in a more interactive process.

In summary, the students in Group A, who held democratic discussions, participated in various ways, with each student playing a different role according to his/her abilities in each PBL phase. On the other hand, the members of Group B, who solved the problem on the basis of one person's arbitrary decisions, were limited in terms of their participation in each project stage, with their differences in ability fixed from the beginning. Figure 5 shows the interaction types and the process of change in the PBL stages for Groups A and B.

Motivation

IMMS & CIS results

The students' scores on the IMMS and CIS (see Tables 6 and 7) were higher after PBL than before, except for Student 6 in Group B. The self-reported questionnaires reveal the members' self-perceptions of their learning motivation. Therefore, it is evident that most of the participants recognized that the PBL activity conducted in this study had a positive effect on learning motivation.

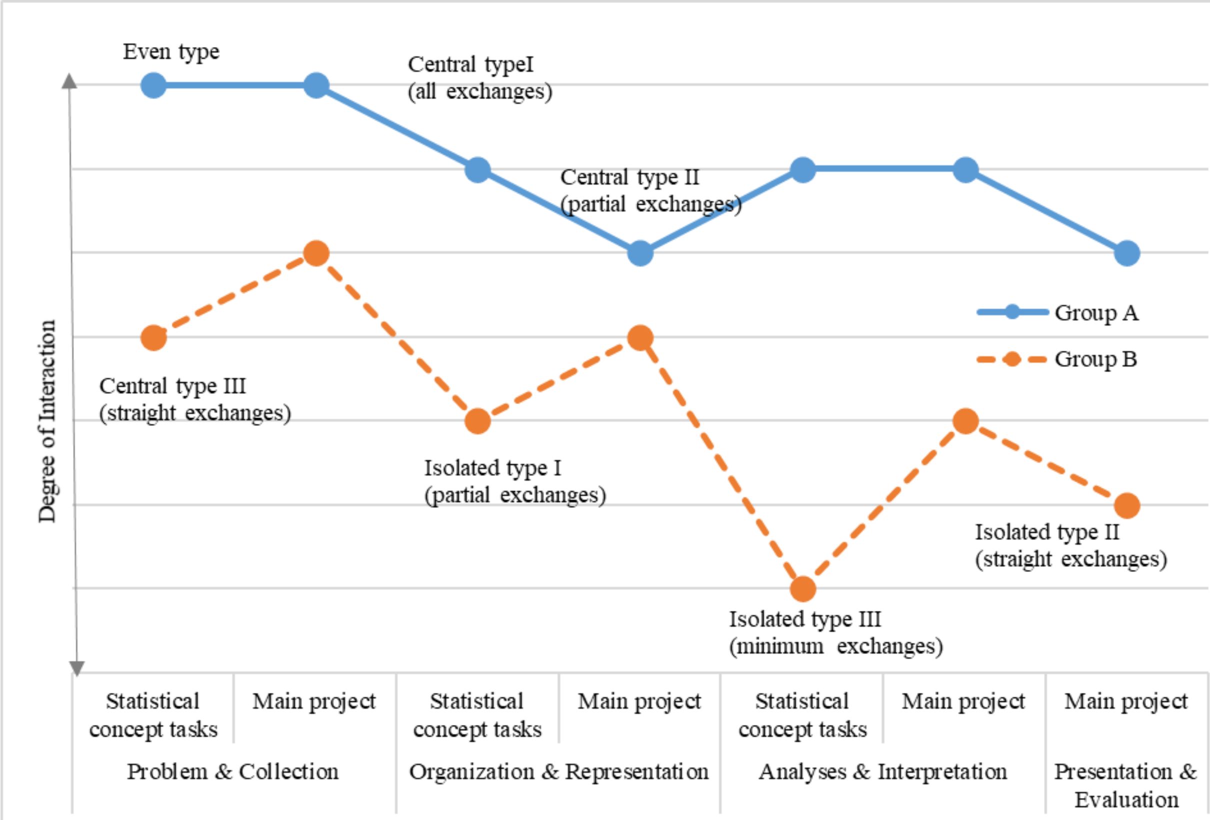


Figure 5. Types of interaction shown at each PBL stage

Table 6. IMMS results of students in Groups A & B

Students / Motivation	Group A								Group B							
	S1		S2		S3		S4		S5		S6		S7		S8	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
A	2.91	3.82	3.45	5.00	3.55	4.73	2.91	3.55	3.00	3.55	3.36	2.45	2.55	3.73	3.00	4.00
R	3.25	4.00	4.63	5.00	3.63	4.13	3.75	3.50	3.00	3.75	3.38	2.75	3.25	3.63	3.00	4.25
C	2.80	4.00	4.80	4.80	4.00	4.20	3.00	3.40	3.00	3.80	3.20	2.80	3.20	4.00	3.80	4.60
S	3.67	4.17	4.50	5.00	3.50	4.83	3.50	3.67	3.33	4.00	3.17	3.00	3.17	4.17	2.83	3.83
TOTAL	3.13	3.97	4.2	4.97	3.63	4.5	3.27	3.53	3.07	3.73	3.3	2.7	2.97	3.83	3.1	4.13

Note. S1 = Student 1

Table 7. CIS results of students in Groups A & B

Students / Motivation	Group A								Group B							
	S1		S2		S3		S4		S5		S6		S7		S8	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
A	3.00	4.33	4.17	5.00	3.17	4.17	3.00	4.00	3.00	4.00	4.17	2.17	3.33	4.00	4.00	5.00
R	3.33	4.17	4.33	5.00	4.00	4.17	4.83	4.83	3.00	4.00	3.67	2.83	4.00	4.33	4.00	5.00
C	3.14	4.14	3.71	5.00	3.43	4.57	3.14	3.86	3.00	3.71	3.86	2.57	3.29	4.00	4.00	4.86
S	2.83	4.17	5.00	5.00	4.17	4.17	3.50	4.00	3.00	4.00	3.33	2.17	3.17	4.33	4.00	4.83
TOTAL	3.08	4.20	4.44	4.84	3.68	4.28	3.60	3.80	3.00	3.92	3.76	2.44	3.44	4.16	3.84	4.92

Note. S1 = Student 1

Results from ARCS analysis framework

There was a large difference in the level of learning motivation and the change in that level pre/post intervention between the members of Group A and Group B. Most of the members of Group A showed motivation levels within the acceptable range, while the members of Group B tended to show too much or too little motivation. In Group A, which democratically solved the problem, the number of motivation factors that were deemed to be too low or too high gradually decreased and remained within the acceptable range in the latter part of the project. However, in Group B, which relied on the leader's arbitrary decisions, there were more cases in which the level of motivation was too high or too low.

It appears that the learning motivation of the students who moved away to excessive or insufficient levels remained unchanged. They seem to be difficult to move

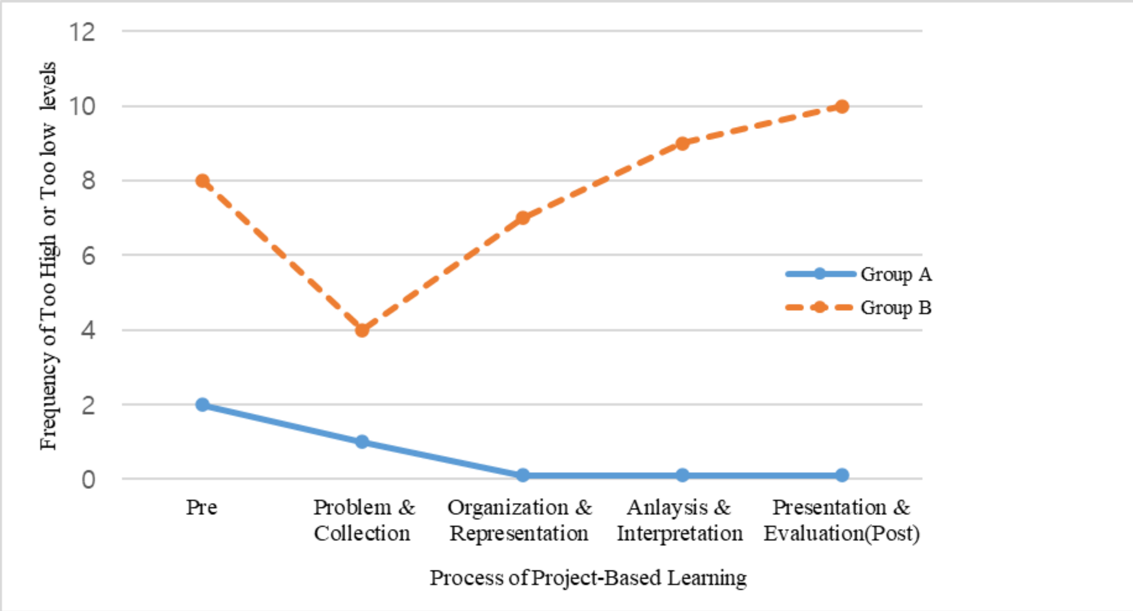
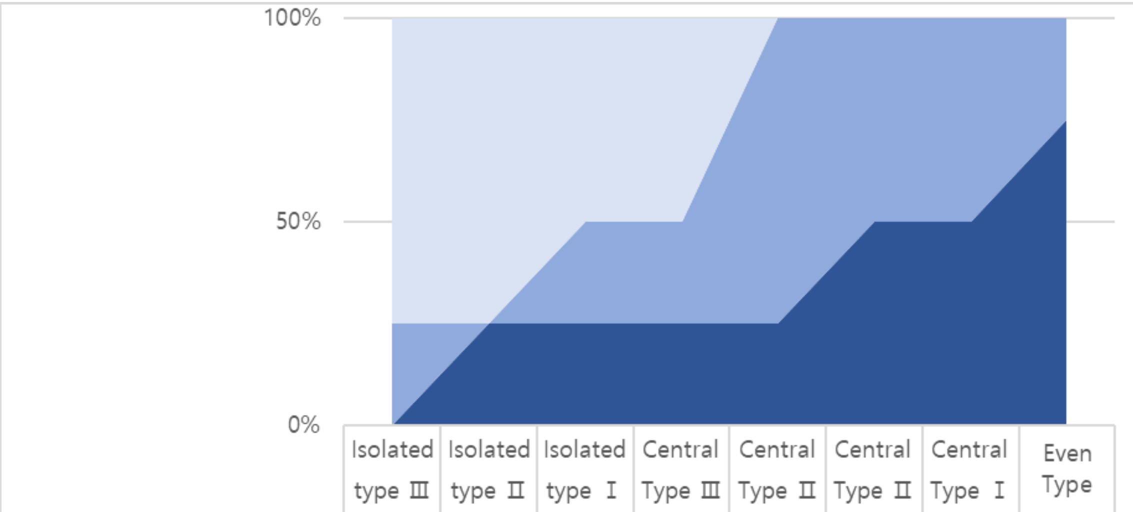


Figure 6. Changes in ARCS levels at each stage of PBL



	Isolated type Ⅲ	Isolated type Ⅱ	Isolated type Ⅰ	Central Type Ⅲ	Central Type Ⅱ	Central Type Ⅱ	Central Type Ⅰ	Even Type
Too high, Too low	3	3	2	2				
Too high/Acceptable, Too low/Acceptable	1		1	1	3	2	2	1
Acceptable		1	1	1	1	2	2	3

Figure 7. Relationship between interaction type and level of learning motivation

to acceptable level. Considering this finding, it seems that the general mood when discussing the problem-solving process and the attitude between the group members influence the changes in the level of learning motivation. This supports the results of Shaw (1976), who showed that various elements of communication influence the degree of satisfaction of group members (see Figure 6).

Motivation Level by Type of Interaction

An examination of the relationship between interaction type and learning motivation level in the two groups revealed the following: the more excessive or insufficient factors there were contributing to the learning motivation level, the type of inactive interaction. On the other hand, as the number of factors in the acceptable level and the moderate range (too high/acceptable, acceptable/too low) increases, the type of active interaction, indicating that the degree of interaction and the level of learning motivation are related. Figure 7 shows the frequency of learning motivation level according to interaction type.

CONCLUSION

This case study examined the degree of interaction and change in learning motivation for two groups that exhibited differences in the discussion process during a PBL activity.

First, due to differences in the discussion process, the two groups showed significant differences in type of interaction throughout the project. Characteristically, however, the most active type of interaction emerged in both groups at the "Problem and Collection" stage, an ill-structured task without fixed answers. Both groups were led by students with good math knowledge. Group A shared knowledge and changed flexibly depending on the situation. However, the leader of Group B arbitrarily solved the problem. As a result, low-educated students as well as a math gifted student participated passively. This is in line with the work of Blumenfeld and colleagues (1991), which considered ways to increase student participation in the design of PBL assignments. We also support the results of Kim (2018), and Yeo et al. (2018), who showed that more collaboration occurs when roles are flexible according to members' circumstances or capabilities. In addition, both groups showed the most active interactions when solving complex mathematical tasks with no fixed answers, such as the 'problem setting and data collection' task. This finding is similar to the results of Shaw (1976), which showed that a decentralized network, such as an all-channel network, allows for free expression of one's own thoughts and opinions, leading to presentation of creative solutions Therefore, when designing a PBL activity, it is important to consider the characteristics of the assignment, to provide roles and opportunities for each student to contribute to the problem-solving process, and to ensure that there is proper coordination in the discussion process.

Second, the learning motivation change patterns of the two groups differed markedly during the project. In other words, the more active the discussion, the more likely the learning motivation (ARCS) element of group members changed within the appropriate range. Based on these results, we would like to discuss the need to explore learning motivations from a social interaction perspective. It is important to understand that learning motivation is an individual issue that can change through interactions with others. Therefore, when developing a motivational strategy in PBL, it is necessary to examine the characteristics of motivation that are changed by the collaborative situation, and to design motivational strategies to enhance individual learning motivation. In addition, motivation should be measured in a variety of ways throughout the learning process. In this context, it is necessary to explore learning motivation changes of group members affected by each other as well as individual learning motivation by measuring learning motivation in various ways during the course. Prior studies examining the effect of learning motivation in PBL (Kang et al., 2018; Ryu & Seo, 2014) mainly relied on quantitative analysis using pre-test & post-test scores to measure learning motivation. However, there were slight differences between the actual task performance observed by the researcher during the main project and the level of motivation according to the test papers. This is because young students are not clearly aware of their state of learning motivation, and/or because the understanding of motivation varies from student to student and constantly changes over the course of the project.

Third, the more active types of interactions, the more "acceptable" levels of learning motivation, and the more "too low or too high" levels of interactions. From this result, it can be inferred that the interaction type and the learning motivation level cyclically influence one another in a PBL environment. Since many complex factors influence interaction and learning motivation, it is not easy to clarify a causal relationship between the two. Although there are limitations in generalizing the study results of just 8 students, this study showed that prior learning motivation determines the interaction type, and the interaction type has an influence on the post-learning motivation, indicating that a dynamic relationship exists between the two. Studies on factors that influence interactions (Kim & Cho, 2018; Lim et al., 2009) and studies on learning motivation (Lee & Song, 2018; Ok, 2009) are steadily being conducted. It is expected that a follow-up study will be conducted on how the factors of interaction and learning motivation are related.

With the advent of post COVID-19 era, collaboration and social communication methods are changing through mixed learning. Measures to strengthen them are emerging as a new topic. The Ministry of Education (2020) also announced 10 policy tasks (proposal) for the transition to future education after COVID-19 and emphasized fostering future talents with creativity and collaboration skills to create new knowledge and values self-directly.

Along with this trend of time, we are facing new challenges that encourage students to voluntarily access smart devices and participate in online classes. In this regard, studies on learning motivation in online lectures (Kim et al., 2020; Lee & Ha, 2016) have raised the need to understand characteristics of learning motivation in advance and suggested that it could be promoted by the instructor's active role. Therefore, results of this study are meaningful in that they provide instructors with various implications for learning motivation and various types of interactions that could lead to student participation.

This study was conducted through eight cases of participation in offline classes. The situation between online and offline is not expected to be much different in that students' voluntary participation and active interaction through learning motivation are inseparable. In other words, in a cooperative situation, an individual's learning motivation can be influenced not only by personal variables, but also by social relations in a cooperative situation. Based on results of this study, roles of teachers and students can be suggested as follows.

Teachers should analyze characteristics of project tasks according to the changing environment and provide roles and opportunities for participation at the student level so that students can feel "I am contributing to this task." The group with this experience will have active interaction and improved learning motivation. During the project, teachers should continue to pay attention to learner motivation and monitor students so that they can have positive learning motivation. In addition, students should continue to strive to reduce factors that negatively affect the cooperative process and become active learners by understanding themselves through various test tools related to learning motivation.

Since this study obtained results from eight cases of participating in offline classes, a follow-up study on how these types of interactions between students performed offline would differ from those online is needed. In addition, research on how to induce and maintain students' motivation in mixed learning situations needs to be conducted. Moreover, as mentioned earlier, if various studies are conducted that can measure learning motivation from various angles, they will contribute to the creation of meaningful classes for teachers and students.

Author notes: This material is based on parts of a dissertation titled, "A case study on types of interaction and learning motivation in small group activities of project-based learning - with a focus on the "*data and possibilities*" content in elementary math" by the first author.

Author contributions: All authors have sufficiently contributed to the study, and agreed with the results and conclusions.

Funding: No funding source is reported for this study.

Declaration of interest: No conflict of interest is declared by authors.

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