Elements to Improve the Quality of Students' Collaboration in Mathematics Classes

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Abstract

Lachner and Nückles (2016) have pointed out that in mathematics explanations, it is important to include background information such as the rationale for and process for finding the solution. It has also been shown that during learning activities one student teaches another one-on-one, they should explain and ask questions to build knowledge, not just tell the answers (Roscoe & Chi, 2007). In collaborative learning in mathematics, teachers should support students in improving the quality of their collaboration activities, including the mathematical quality and the quality of how they engage in the activities. In this study, we interviewed teachers to develop the pattern materials to improve the quality of student collaboration in mathematics classes. As a result, we identify pattern elements such as what is important, why it is important, background situations, and possible problems when incorporating interactive activities in mathematics classes. In addition, we divided these elements into the categories of context, problem, solution, and consequence.

Keywords: Collaborative Learning, Interview Study, Mathematics Education, Pattern Language

Introduction

Collaborative learning is the process by which learners interact in small groups to learn effectively (Slavin, 2014). Working together in small groups on tasks has been found to have a significant positive effect on mathematics performance and attitudes toward mathematics among students (e.g., Hossain, 2018). However, simply providing opportunities for group work does not result in effective collaborative learning (Brush, 1998). Lachner and Nückles (2016) have pointed out that in mathematics explanations, it is important to include background information such as the rationale for and process for finding the solution. It has also been shown that while learning activities one student teaches another one-on-one, they should explain and ask questions to build knowledge, not just tell their answers (Roscoe & Chi, 2007). In collaborative learning in mathematics, teachers should support students in improving the quality of their collaboration activities, including the mathematical quality and the quality of how they do the activities.

Efforts to improve the quality of student collaboration in the classroom include providing training in collaboration activities and the teaching of effective skills. Prichard et al. (2006) showed that team-skills training can enhance the performance of collaborative groups, but noted that these benefits may be lost if trained groups are

disrupted. In a study conducted in Japan, Fukaya et al. (2016) demonstrated that teaching effective student-to-student learning methods (e.g., the use of concrete examples in explanations) before collaboration activities can promote the use of these methods and the understanding of the learning content. However, methods such as re-explaining the material one has learned from partners to confirm understanding were rarely used. In addition, Brodie (2000) points out that teachers are unable to effectively monitor the activities when there are many groups, and they are not always able to intervene appropriately. Based on the above, we find it necessary to provide continuous support to students so that they can independently use the skills and methods required when needed to improve the quality of their student-to-student in-class learning activities.

This study was based on the concept of Pattern Languages. A Pattern Language is a set of patterns (rules of thumb described in the form of (a) situations, (b) problems, (c) solutions, and (d) results), and users select patterns according to their situations and concretize and practice the abstract solutions described in the patterns (Iba & Furukawazono, 2013). Therefore, we expect that students will refer to the pattern materials, use effective skills, and improve the quality of their activities in mathematics classes. However, to develop the pattern materials to be used in the mathematics classroom, it is necessary to determine the elements for improving the quality of collaboration activities, taking into account the characteristics of the subject of mathematics. We refer to such elements in this study as pattern elements.

The purpose of this study was to determine the pattern elements for improving the quality of student collaboration in mathematics classes. This research was conducted in preparation for the development of the pattern materials that provide support for students to improve the quality of their collaborative learning activities.

Method

For the development of the pattern materials that provide support for students to improve the quality of their activities, we need to identify the following elements: (a) the background situations that may arise when incorporating collaboration activities in the mathematics classes (situations), (b) the problems that may arise (problems), (c) the important factors, methods, and skills involved in collaboration activities in mathematics classes (solutions), and (d) the reasons why they are important and the ideal situations in which the problems are solved (results).

Following the process of creating pattern language given by Iba & Isaku (2016), we collected elements for the pattern materials from interviews. Interviews were conducted between December 2021 and March 2022 with nine mathematics teachers who routinely incorporated collaboration activities into their classroom instruction. Participants were first asked to talk about their actual practices. Next, they were asked questions about the ideas and motives behind their practices. Then, they were asked abstract questions about what they thought was important for effective student-to-student activities in the classes, and additional questions were asked in response to their answers for us to better understand their experiences. We recorded the interviews with the participants' consent. The interviews were transcribed by the first author and the elements were considered by several people together with other members of the first author's laboratory who were familiar with the study.

Results

The interviews were conducted in Japanese, and **Table 1** presents the English translations of sample statements. The underlined text in (1) shows the situation in which students show their answers to each other, and the answers are different. We extracted it as “situations”. The underlined text in (2) shows the problem of students not being confident

in their answers. We extracted it as "problems". The underlined text in (3) shows the solution of the students re-discussing each other's processes and formulae. We extracted it as "solutions". The underlined text in (4) shows the result that the listener developed the ability to solve the mathematical problems on his or her own. We extracted it as "results".

This method was used to collect the pattern elements of situations, problems, solutions, and results from the contents of the interviews. **Table 2** provides examples of the elements.

Table 1

Sample statements from the interviews

Participant	Statements	Coded elements
Teacher A	If the students show their answers to each other and the answers are the same, that's fine, but if (1)they are different, which one is wrong… (2)they tend to be unsure which one is wrong, and many of them tend to think that I'm wrong anyway. So, it would be good to be able to (3)compare the formulae again, talk about them, compare how you solved them, and then discuss which one seems more likely to be correct. I explain such things to my students.	(1) Situations (2) Problems (3) Solutions
Teacher B	For example, when a listener does not understand an equation question, instead of just telling them how to solve it, show them how to get to the halfway point and ask them to try the rest. … (4)I want the listeners to develop the ability to solve problems on their own (and I want the speaker to provide such support).	(4) Results
Teacher C	Both the listener and the speaker are the ones who create the situation, so (5)if the listener feels that something is a little strange or different, it is always better to talk about it because it is for the other person's benefit.	(5) Solutions

Table 2

Examples of identified pattern elements

Type of element	Pattern elements
Situations	· Students show their answers to each other, and the answers are different. · The student only listens to his or her partner's explanation. · Students who are good at mathematics have more work to do.
Problems	· Students are not confident in their answers. · The listener tries to solve it again, but they can not. · Students can give answers, but they cannot express them well.
Solutions	· The students re-discuss each other's solution processes and formulae. · The listener asks even the smallest questions. · The students review the logical connections one by one, e.g., if A, then B, if B, then C.
Results	· The listener develops the ability to solve the mathematical problems on his or her own. · Students can fix small mistakes by themselves. · Students focus on the activity instead of relying on the teacher.

Conclusion

In this study, we conducted interviews with mathematics teachers to determine the pattern elements for improving the quality of students' collaboration activities in mathematics classes, in the form of situations, problems, solutions, and results. In the future, we will narrow down the number of elements by integrating those that are highly

similar and abstracting those that are too specific. In addition, Further studies should link the relevant elements together and develop pattern materials that students can refer to in class. For example, in Table 1, (4) and (5) are the statements of different persons, but are considered to be related. With the pattern materials, situations, problems, solutions, and outcomes will be linked, which would help students identify their situations and possible problems, and use the skills proposed as solutions.

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