Designing tasks and finding strategies for promoting student-to-student interaction

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To reach the goals of communication and reasoning in mathematics in upper secondary school, students need to talk about mathematics but sometimes this is not as easy to achieve as it first seems. In this paper, an initial analysis is provided of tasks and strategies from an educational design research project promoting student-to-student interaction. The data include students' interactions and perceptions on working with mathematics in groups from the first of three cycles. They are analysed and discussed in relationship to the choice of analytical tools, means of support and tasks for the remaining cycles.

Introduction

Skolinspektionen, the Swedish School Inspection Department (2010), criticized the fact that in many upper secondary mathematics classrooms, students do too much individual work in textbooks. The introduction of a new syllabus in mathematics in 2011 (Skolverket (the Swedish National Agency for Education), 2012) increased the focus on communication and reasoning abilities. Consequently, there is a need to investigate how to achieve this focus. In my larger research project, tasks are introduced which were designed to improve students' mathematical communication abilities. The research questions are: How do interactions and perceptions change over time when different tasks are provided to increase student-to-student interaction? What kind of strategies and tasks promote student-to-student interaction? Here the first question focuses on students' perspectives, while the second is on the pedagogical choices made in the project. In this paper, an analysis of the implementation of the first set of tasks is described in regard to the implications for further tasks.

The study is conducted in a first year, upper secondary classroom in a city in Sweden. The teacher was interested in trying new strategies concerning student interaction. Almost all students in the class have foreign backgrounds, which according to Skolverket (2013), means that they were born abroad or born in Sweden with both parents born abroad. Since almost one quarter of all students in Swedish upper secondary schools have foreign backgrounds (Skolverket, 2013), it is common that at least some students in a classroom do not have Swedish as their first language. Van Eerde, Hajer and Prenger (2008) claimed that second language learners "need to actively use and produce new linguistic elements" (p. 34). However, this may also be the case for first language speakers, since it is crucial for all mathematics students to explain, reason and justify (Brandt & Schütte, 2010).

Background to the study

In order to study increased student-to-student interaction, this project uses educational design research (EDR) (McKenney & Reeves, 2012). EDR allows for tasks to be designed flexibly and supports ongoing changes in teaching practices. EDR is a cyclic process in which each cycle contains three phases: analysis/exploration, design and evaluation (McKenney & Reeves, 2012). Working through the phases provides opportunities for improving the tasks but also for producing theoretical understandings (McKenney & Reeves, 2012; Van den Akker, Gravemeijer, McKenney & Nieveen, 2006). In this project, the focus is on developing theory on student-to-student interaction, while developing a practical intervention.

The project consists of three design cycles that have mathematical as well as student interaction goals. In EDR, the choices made in each cycle need to be theoretically justified (McKenney & Reeves, 2012). Thus in this case, the designs are developed from theories on interaction and mathematical communication. Therefore, design means not only the tasks given to the students, but also the means of support for student-to-student interaction and the organisation for lessons in which the tasks are implemented.

Since research concerning student-to-student interaction in multilingual upper secondary mathematics classrooms appears to be limited (see Goos, Galbraith & Renshaw, 2002; Forster & Taylor, 2003), theories are drawn from research with younger students or in monolingual settings. A starting point has been theories on cooperative learning, which is a family of methods in which students learn in small groups and take responsibility for each other's learning (Brandell & Backlund, 2011). In cooperative learning, it is important that there is a positive interdependence between the students, so that the students have the common goal of solving tasks together. To be successful with the tasks, all students need to succeed. Walshaw and Anthony (2008) claimed that group work gives students opportunities to express their thinking and that "small group work can provide the context for social and cognitive engagement" (p. 142).

However, not all group work is effective. Sfard and Kieran (2001) provided an example of an unsuccessful collaboration and concluded that just because students talk, it does not mean that they learn. Another example is Fuentes's (2013) action research project that identified issues preventing effective communication, such as the promotion of communication, the quality of the communication and socio-cultural norms (Fuentes, 2013).

In order to overcome some of the difficulties identified with group work, Alrø and Skovsmose's (2004) inquiry cooperation model (IC-model) was used as a theoretical base for the first cycle. It describes how to create opportunities for rich conversations about mathematics. This model usually concerns teacher-student mathematical communication, but in this study was applied to student-to-student communication. It allowed student interactions to be analysed by the type of communication acts about the mathematical tasks. The communicative acts were: *getting in contact*, *locating*, *identifying*, *advocating*, *thinking aloud*, *reformulating*, *challenging* and *evaluating*. Although, Alrø and Skovsmose (2004) claimed that it is not common to find fully developed IC-models in classrooms, it seemed a valuable way of understanding how the students interacted together to solve mathematical tasks.

In this project, three cycles are conducted during one semester. Students are audio-recorded while working with the tasks. They also complete a questionnaire and are interviewed in groups of two to four students after each cycle.

The first design cycle

Goals

In the first design cycle, the mathematical goal was to develop students' mathematical problem-solving strategies. Problem solving is a part of mathematics in which the answer and/or the solution methods are not directly apparent to the students (Schoenfeld, 1983). Initially this had seemed an appropriate context for encouraging the students to discuss mathematics with each other. The goal concerning group work and communication was that all students would participate actively in mathematical conversations, since if they were not active it would be hard for them to develop their communication and reasoning abilities. In the first cycle, the findings about student interactions and perceptions provide a base for how tasks and strategies could be developed in the following cycles in order to promote student-to-student interaction.

The analysis and exploration phase

In this phase, the context of the class was analysed by observing the mathematics lessons for a month. The observations indicated that almost all lessons had the same structure: a whole-class discussion about the content in a movie that the students had watched as homework and after that the students worked with textbook tasks while they were seated in groups of four students. Sometimes the teacher gave them a group task.

In some groups, there was very little mathematical communication with only some students being active. Often, the students continued to work individually or some students dominated the conversations. Fuentes's (2013) research had noted similar problems in the group work she observed.

The design phase

Consequently, tasks for promoting student-to-student interaction as well as means of support for helping students to communicate were designed in cooperation with the teacher. The students were divided into new groups, still with four students in each group. In previous research (see Deen & Zuidema, 2008; Fuentes, 2013) groups of four had also been used.

As group interaction needed to be more effective, the focus for the tasks in this first cycle became not to introduce new mathematical concepts, but to increase the quantity and quality of student interactions, based on the IC-model (Alrø & Skovsmose, 2004). The tasks were designed to support students to use the dialogic acts of the model by talking to each other (*getting in contact*), understanding the problem (*locating*) and trying out different problem-solving strategies (*advocating*). It was considered that their conversations could include the acts of *identifying, thinking aloud* and *reformulating*, depending on the content of the conversations. The act *evaluating* would be covered in the final whole class discussion, but could occur also in the group talks. At this stage, it was decided not to focus on supporting students to *challenge* each other's ideas. Instead the teacher was to do this when visiting the groups. This was one of the differences from using the IC-model to understand teacher-student interaction, which the model initially was developed for, to focusing on student-to-student interaction. A teacher's role can include naturally *challenging* of students' mathematical thinking, but students may not consider that they should follow up on others' utterances and ask for clarifications or justifications of claims.

The first problem that the students had to solve in groups involved fractions:

> Marie and Johannes need to paint a fence. If Marie does the painting herself it will take 4 hours. If Johannes does it, it will only take 2 hours, since he has a broader brush. They need 10 litres of paint for the fence. How long will it take to paint the fence if they cooperate and paint the fence together?

The second problem described a competition between groups of students that could best be solved with the help of probability reasoning. The problem was:

> Two dice are thrown. Guess the sum of the dots on the dice to win the game.

At the end of the lesson, each group had to pic one number between 1 and 12, and the group with the right guess won chocolate when the dice were thrown. The task was to reason mathematically together about which number to pic in order to increase the chance to win the game.

The analysis/exploration phase had reinforced Sfard and Kieran's (2001) warning that "the art of communicating has to be taught" (p. 71). So to do this, it was decided to give the students: a sheet about problem solving, a question list, and roles in the group work. There were several reasons for choosing these means of support. Rojas-Drummond and Mercer (2003) claimed that it is important to teach the procedures for problem solving. Hence, students were given a list of questions for when they began a problem-solving task. Mercer (1995) claimed that when teachers ask students questions, students get at chance to “check, refine and elaborate” (p. 10) and in this cycle it was considered that students could help each other to do this with the support of a question list and by writing down the group’s important mathematical questions. These would be followed-up in a whole-class discussion at the end of the lesson. Finally, to support the students becoming positively interdependent on each other, the group roles identified different responsibilities. The roles were: Chairperson, who was responsible for deciding who talked when; Summarizer, who was responsible for making short summaries about what the group concluded; Thinker, who was responsible for talking aloud about his/her thoughts; and Accountant, who was responsible for showing the group’s solutions to the teacher and/or the class. All of the students were Questioners and so expected to ask each other questions.

Results from the design phase

To determine if the two groups’ interactions had improved from what was seen in the initial observations, students’ utterances were compared to different acts in the IC-model. Interviews and questionnaire responses were used to verify classifying the utterances according to this model. As the evaluation of the first cycle, this material provides base line data for comparisons with later cycles. This comparison will contribute to responding to the two research questions, particularly the one about changes to interactions over time.

One group consisted of four boys, who all spoke different first languages. One boy, Carlos, started in the class a few weeks later than the others. Usually during the lessons, they were loud but on task. Azad had a leading position in the group. He talked often and enjoyed explaining mathematics to the others.

During the task about the fence, Azad had the role of the Accountant but talked most of the time. Meanwhile, Carlos, who was the Thinker, only expressed his opinion a few times during the twenty-minute conversation. Another boy, Mustafa, who was the Summarizer, was quiet in the beginning, but after some thinking-time started communicating with the others. Mohammed, the Chairperson, was active throughout the discussion, but did not take on the role as Chairperson. Instead he talked to his peers as he usually did.

All four students were focused on the task about the fence and initially there seemed to be a lot of *getting in contact* and *locating* when the students tried to understand how the painting of the wall could be divided between the persons and how much time different fractions of the wall would take for them to paint. At the same time, there was a kind of competition about who should be speaking, especially between Mustafa and Azad. They were not always competitive and often ended their sentences with tag questions, such as “okay?” or “do you understand?”. This can be connected to the act *getting in contact*, which Alrø and

Skovsmose (2004) described as “tuning in on the co-participant and his or her perspectives” (p. 101). The tag questions made it possible to ensure that the other students could follow the mathematical reasoning.

For the task about the dice sum, the roles were changed and Carlos took a more dominant role as Chairperson. He was active in the discussions and everyone got more space to talk except Azad, who was grumpish and frustrated that he could not talk as much as he used to. The competition about talking time continued. However, in the first cycle interviews, the four boys stated that they liked working together. In the questionnaire, there were no clear differences related to how much they talked. Carlos, who talked the least, claimed that he was active in the discussions and that they all listened to each other. He thought that working with different roles was good. The only one who thought the roles did not work was Azad, who said that everyone just talked the way they wanted.

In the interview Mohammed said that Azad talked a lot, but that this was good. He called Azad “the king” and said that he liked that someone was the leader in the discussions, since otherwise it was hard to know what to do. However, although Mohammed focused on the benefits of this, Mercer (1995) warned that when students have different mathematical knowledge, it may be that a student “who dominates decision-making and insists on the use of their own problem-solving strategies may hinder rather then help the less able” (p. 93).

The group did not have time to finish the task about the fence. When the solutions were presented in a whole-class discussion, Azad said “The task was easy, but we made it much harder than it was. I actually felt stupid after I saw the answer”. (Den var enkel, fast vi gjorde den mycket svårare än den var. Jag kände mig dum efter jag fick se svaret faktiskt).

In another group, two of the group members were the girls, Aisha and Mariam. They worked closely together for both tasks, while the other group members varied. There was a lot of *reformulating* as they continuously completed each other’s sentences and helped each other with calculations during the conversation. From the recordings it was not possible to determine who had which role, which suggests that they did not follow the roles. When the group could not find the right answer, they became frustrated. They focused on the word “motivera” (justify) in the task. Another girl in the group, Nour, stated:

> Nour: I hate when they say justify. I hate that word, in all school subjects. Yes. Justify. What do they mean justify? Especially in maths. You cannot justify. You think. Justify. It is something inside your head. (Jag hatar när de säger motivera. Jag hatar det här ordet, i alla ämnen. Ja. Motivera. Vadå motivera? Särskilt i matte. Man kan inte motivera. Man tänker. Motivera. Det är alltså något man har i huvudet.)

The girls tried to *get in contact* and *locate* the mathematics in the problem, but did not succeed as they started with guessing an answer and then trying to count backwards, not using fractions that they currently were working with during mathematics lessons. Alrø and Skovsmose (2004) claimed that emotive aspects, such as mutual respect, responsibility and confidence are important for the learning process and that there might be a risk that "the loss of contact became a hindrance for the co-operation" (p. 101). The group got stuck because they could not find the correct answer and they did not know how to mathematically justify their guesses. The general advice about using the problem-solving sheet did not help and they were not *challenged* in their thinking.

During the task about the dice sum, Mariam and Aisha's group continued to focus on getting the correct answer. Such an approach has been identified as problematic. Mercer (1995) stated that "students may be more worried about 'doing the right thing' than with thinking things through" (p. 28). Another issue for this group was that there was a lot of focus on students' attitudes to mathematics, such as the discussion about justifications. Another example is when Aisha and Mariam, talking over the top of each other, claimed:

Aisha/Mariam: But how? We cannot win, they are better… but you have to try. We are not… We are so stupid compared to the others. We are. We are. (Alltså hur? Vi kommer inte ens vinna, de är bättre… alltså du måste försöka göra det. Vi är inte… Vi är så dumma jämfört med de andra. Det är vi. Det är vi.)

In the interviews the girls claimed that much of their feelings about being stupid could be because they did not find the correct solution. They claimed that it was central to try out different problem-solving strategies, but that they were very focused on the answers. However, when Aisha stated that she was no good at mathematics in the interview, Mariam and another group member told her that it was untrue and reminded Aisha that she had helped them with mathematics tasks earlier that day. The atmosphere in the group seemed supportive.

The evaluation phase and implications for the second design cycle

The analysis of the group work contributed to the evaluation phase in which design ideas and tasks are empirically tested (McKenney & Reeves, 2012). In the evaluation phase conclusions are made about which pedagogical aspects need to be reconsidered in the next cycle and how tasks and means of support need to be changed to promote student-to-student communication. The results implied that Walshaw and Anthony's (2008) thoughts that group work promotes social and cognitive engagement were only partly shown in the first cycle. Although the students did actively engage and talk about the mathematical content and worked with problem-solving strategies, their contributions varied. Limited attempts to follow the roles were made. They did not use their question lists actively, which made a meta-level whole-class discussion about questions difficult.

Consequently in the second cycle, the plan is to refine the strategies to support students' interaction. Alrø and Skovsmose (2004) mentioned that finding a fully developed IC-model is rare, and the results of the analysis showed that only certain elements of the IC-model were identifiable in this first cycle.

There were also unexpected findings such as students' feelings about being stupid or competition to dominate the conversations, which needed to be dealt with in the next cycle if the interactions were to improve students' opportunities to learn mathematics. As Esmonde (2009) claimed, group work can produce "undesirable social interaction styles" (p. 1009). Another problem was that the groups were very focused on getting the correct answer and not on using different problem-solving strategies. Therefore, in the second cycle, tasks will be chosen that have more than one answer. Also, students will be encouraged to ask quiet group members questions and to try different strategies to solve problems.

Another result from this cycle was that most of the students did not follow the roles, so changes are needed in the descriptions of the roles. Esmonde (2009) claimed that group roles contribute to equitable learning opportunities, only if students consider the roles to be important, understand the reasons for them and agree to try them out. For instance, since no one listened to the Chairperson about who could talk, there is no reason to include this role for the new tasks. In one of the groups, Azad took the role of the leader, without having this as his designated role, yet the others seemed to accept this. For the new tasks, there will be a Groupwork-leader responsible for thinking about the group and if someone is too quiet to ask him/her questions. There will also be a Questioner responsible for highlighting mathematical questions, at least one from each person in the group, a Writer responsible for the written report to the teacher and a Teller responsible for telling the rest of the class about the solutions. After the task there will be a meta-discussion about the roles and how the cooperation worked and a second attempt at a meta-level discussion on mathematical questions.

Another factor that may affect how the groups worked is different students' needs. For instance on the task about the fence, Mustafa claimed in the interview that he needed some time to think about the task before he entered the discussion, while Azad started talking straight away. For the next cycle, some individual thinking time will be added before the group discussions begin so that everyone gets a chance to prepare for making a contribution.

Conclusion

The aim of this EDR-study is to improve understandings about how to increase student-to-student interactions both from the task design perspective but also from the students' own perspective. This was deemed as important both because of the new emphases in the syllabus but also because initial observations showed limited mathematical communication in relation to the acts in the IC-model occurring in the classroom. Results from the first cycle show that it was possible to improve students' contributions to mathematical discussions about problem-solving tasks. However, some strategies needed to be changed for the next cycle so that the quality as well as the quantity of students' contributions increases.

These changes include designing tasks in order to avoid the search for the right answer and using strategies that make students more confident about their mathematical abilities, for instance through making the roles more interactive in that the students invite each other to contribute to the group discussions. The social structures in the groups and students' attitudes towards mathematics are shown to be important.

The strength of using an EDR-approach in this project is that the cyclic nature makes it possible to improve the designs in a flexible way to meet the needs of the students, needs that may not be apparent before the first task. For example, the first cycle indicated that students' perceptions of how good they are at mathematics and their attitudes to problem-solving situations are important features and need to be taken into consideration when trying to promote rich learning opportunities.

EDR is also a method for researchers in mathematics education to find and improve theoretical tools for studying student communication and develop deeper understanding on student-to-student interaction. In this project, the first cycle shows that there is a need to analyse the structure of the student interaction in more depth. The acts in the IC-model, although useful for planning activities, seemed to not be so helpful when analysing data. For the second cycle, the theoretical base in the design phase will be complemented by Fuentes's (2013) framework for analysing student communication. This framework contains eight different communication patterns between students, which will be used with an analysis of the different dialogic acts from the IC-model that appeared in the students' interactions.

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