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

Marie Sjöblom
Malmö University

To reach the goals of communication and reasoning in mathematics in upper secondary school, students need to talk about mathematics. In this paper, tasks and strategies for an educational design research project are described. The focus is on how to promote student-to-student interaction and includes a first analysis of students' interactions and perceptions on working with mathematics in groups. Educational design research is a cyclic process and in this paper the first of three cycles is analysed and discussed in relationship to the implications for the choice of analysis tools and new tasks in 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. In my research project, different tasks are introduced with the intention of improving these mathematical 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 strategies and tasks promote student-to-student interaction? In this paper, I analyse the implementation of the first set of tasks by analysing the findings from two groups of students and discuss 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 background, which according to Skolverket (2013), means that they are born abroad or born in Sweden with both parents born abroad. Since about 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. As such, their language needs may be different to those students who have Swedish as a 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). Therefore, all students may need help to develop these abilities.

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 through the development of 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 communication. 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 from each other 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, which means that the students have the common goal of solving the tasks together. To succeed 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 how communication is promoted, the quality of the communication or socio-cultural norms (Fuentes, 2013).

In order to overcome some of the difficulties identified with group work, a theory about mathematical communication, Alrø and Skovsmose's (2004) inquiry cooperation model (IC-model) was used as a theoretical base for the first cycle. This model usually concerns teacher-student 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*. The IC-model provides a theoretical base for how to create opportunities for a rich conversation about mathematics. 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 (or not) to solve the 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 or solving methods are not directly apparent to the students (Schoenfeld, 1983), which can work encouraging for 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.

The analysis and exploration phase

In this phase, the situation in the class was analysed by observing all 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 communication with only some students being active. Often, the students continued to work individually or there were some students who 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 were designed in cooperation with the teacher. The students were divided into new groups with four students in each group. Previous research has used groups of four (see Deen & Zuidema, 2008; Fuentes, 2013).

Given the lack of interaction in the groups, it was decided that the focus for the tasks in this first cycle was not to introduce new mathematical concepts, but to increase the quantity and also the quality of student interactions. Using the IC-model (Alrø & Skovsmose, 2004), the tasks were designed to support students talking to each other (*getting in contact*), understanding the problem formulation (*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, although not a focus, could occur in the group conversations. At this stage, it was decided not to focus on supporting students to *challenge* each other's ideas. Instead the teacher would do this while visiting the groups. This can be seen as a difference when using the IC-model for student-to-student interaction instead of teacher-student interaction, which the model initially was developed for. When there is a teacher present, the *challenging* of students' mathematical thinking is a natural part of conversations, while students might not always choose to follow up on each others utterances and ask for clarifications or justifications of claims.

The first task 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 task involved a competition between different groups of students that could best be solved with the help of probability reasoning. To help the students' interactions, they were given some laboratory materials. The task was:

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

The observations had reinforced Sfard and Kieran's (2001) warning that "the art of communicating has to be taught" (p. 71). Therefore, it was decided to support the students by giving them: a sheet about problem solving, a question list, and personal roles for the group work. There were several reasons for choosing these support means. Rojas-Drummond and Mercer (2003) claimed that it is important to teach procedures on problem solving. Consequently, students were to be given a list of questions to start with when facing 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 also could help each other to do this. So they would be given a question list to highlight the questions that they used and encouraged to write 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 personal roles identified different responsibilities that each student would undertake while solving the tasks. The roles were: Chairperson, who was responsible for deciding who talked when, Summarizer, who was responsible for making small verbal/written summaries of 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 to be Questioners in that they were to ask each other questions.

Results from the design phase

The analysis of two groups of students' interaction was made through connecting students' utterances in the group work to different acts in the IC-model. Interviews and questionnaire responses were used to verify classifying some of the utterances. 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. They had voluntarily sat with each other for all mathematics lessons from the beginning of the academic year, although they did not know each other before. One boy, Carlos, started 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*. At the same time, there was a kind of competition about who should be speaking, especially when Mustafa and Azad both wanted to talk. They were not competitive all the time though 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 group climate made it acceptable to ask questions and admit if they did not understand.

For the task about the dice sum, the roles were changed and Carlos took a more dominant role, as the Chairperson. He was active in the discussions and everyone got more space to talk except for Azad, who was grumpish and frustrated that he could not talk as much as he used to. The competition about talking time continued.

In the first cycle questionnaire and the interviews, the four boys stated that they liked working together. In the questionnaires, there were no clear differences related to how much the students talked. Carlos, who talked the least, claimed that he was active in the group discussions and that they all listened to each other and could express their opinions. He thought that working with different roles was good. The only one who did not like the roles was Azad, who claimed 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 it was good when 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 finish the task about the fence because of a lack of time. 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 utterances. 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 stuck and frustrated. They focused on the word "motivera" (justify) in the task. Another girl, Nour, working with them at that time 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. 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 that they did not know how to 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 new 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 very supportive.

The evaluation phase and implications for the second design cycle

The analysis of the group work contributed the evaluation phase in which design ideas and tasks are empirically tested (McKenney & Reeves, 2012). In the evaluation phase conclusions are made about which aspects needed to be reconsidered in the next design cycle. The results suggested that Walshaw and Anthony's (2008) reflections 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. Some tried the roles, but generally they were not used. 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 for 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 over dominating the conversations, which needed to be dealt with in the next cycle. 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.

For the second cycle, tasks will be chosen that have more than one answer. To prepare the students, a movie about group work will be made that the students will watch as homework and then discuss together. The movie will contain general advices on how to deal with question lists, problem-solving strategies and how to work together as a group. In the second cycle students will be encouraged to ask quiet group members questions and to try out different strategies to solve problems.

Another result of the first cycle is that since most of the students did not follow their roles, changes are needed in the content of the roles. Esmonde’s (2009) claim that roles contribute to equitable learning opportunities, only works 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. 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. In the new setup 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 the different needs of the students. 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 need to be changed for the next cycle so that the quality as well as the quantity of students' contributions increases.

These changes will include designing tasks in a way 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 and tasks in a flexible way to meet the needs of the students, needs that were not apparent before the first task. The first cycle indicates that students' perceptions of how good they are at mathematics and their attitudes in problem-solving situations are important features that need to be taken into consideration when trying to promote rich learning opportunities.

EDR can also be 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, seem to be not so helpful when analysing data. For the second cycle, the theoretical base in the design phase will be changed to build onto not only the IC-model, but also Fuentes's (2013) framework for analysing student communication. This framework contains eight different communication patterns between students, which will be used for the analysis as a complement to what is happening in the different dialogic acts in the IC-model.

References

Alrø, H. & Skovsmose, O. (2004). *Dialogue and learning in mathematics education. Intention, reflection, critique*. Dordrecht: Kluwer Academic Publishers.

Brandell, G. & Backlund, L. (2011). Samarbetslärande i matematik. In G. Brandell & A. Pettersson (Eds.), *Matematikundervisning. Vetenskapliga perspektiv* (pp. 115-148). Stockholm: Stockholms universitets förlag.

Brandt, B. & Schütte, M. (2010). Collective mathematical reasoning in classrooms with a multilingual body of pupils. In U. Gellert, E. Jablonka & C. Morgan (Eds.), *Proceedings of the sixth international mathematics education and society conference* (pp. 111-114). Berlin: Freie Universität Berlin.

Deen J. & Zuidema, N. (2008). Participation, learning and exclusion in group work. In J. Deen, M. Hajer & T. Koole (Eds.), *Interaction in two multicultural mathematics classrooms* (pp. 269-296). Rotterdam: Sense Publishers.

Esmonde, I. (2009). Ideas and identities: supporting equity in cooperative mathematics learning. *Review of educational research 79*(2), 1008-1043.

Forster, P. & Taylor, P. (2003). An investigation of communicative competence in an upper-secondary class where using graphics calculators was routine. *Educational studies in mathematics, 52*(1), 57-77.

Fuentes, S. (2013). Fostering communication between students working collaboratively: results from a practitioner action research study. *Mathematics teacher education and development 15*(1), 48-71.

Goos, M., Galbraith, P., & Renshaw, P. (2002). Socially mediated metacognition: creating collaborative zones of proximal development in small group problem solving. *Educational studies in mathematics, 49*(2), 193-223.

McKenney, S. & Reeves, T. (2012). *Conducting educational design research*. New York: Routledge.

Mercer, N. (1995). *The guided construction of knowledge. Talk amongst teachers and learners*. Clevedon: Multilingual matters.

Rojas-Drummond, S. & Mercer, N. (2003). Scaffolding the development of effective collaboration and learning. *International journal of educational research 39*(1), 99-111.

Schoenfeld, A. (1983). The wild, wild, wild, wild, wild world of problem solving (a review of sorts). *For the learning of mathematics 3*(3), 40-47.

Sfard, A. & Kieran, C. (2001). Cognition as communication: rethinking learning-by-talking through multi-faceted analysis of students' mathematical interactions. *Mind, culture and activity 8*(1), 42-76.

Skolinspektionen (2010). *Undervisningen i matematik i gymnasieskolan. Kvalitetsgranskning. Rapport 2010:13*. (Education in mathematics in upper secondary school. Quality review. Report 2010:13). Reference number: 40-2009:1837.

Skolverket (2012). *Skolverket. Mathematics.* Retrieved 2012-10-10 from http://www.skolverket.se/polopoly_fs/1.174554!/Menu/article/attachment/Mathematics.pdf.

Skolverket (2013). *Skolor och elever i gymnasieskolan läsår 2010/11. Uppgifter på kommunnivå. Tabell 5C.* (Schools and students in upper secondary school, academic year 2010/11. Data at the municipal level. Table 5C.) Retrieved 2013-10-08 from http://www.skolverket.se/statistik-och-utvardering/statistik/gymnasieskola/skolor-och-elever/skolor-och-elever-i-gymnasieskolan-lasar-2012-13-1.192335.

Van Eerde, D., Hajer, M., & Prenger, J. (2008). Promoting mathematics and language learning in interaction. In J. Deen, M. Hajer & T. Koole (Eds.), *Interaction in two multicultural mathematics classrooms* (pp. 31-68). Rotterdam: Sense Publishers.

Van den Akker, J., Gravemeijer, K., McKenney, S., & Nieveen, N. (2006). Introducing educational design research. In J. Van den Akker, K. Gravemijer, S. McKenney and N. Nieveen (Eds.), *Educational design research* (p. 1-8). Oxford: Routledge.

Walshaw, M. & Anthony, G. (2008). Creating productive learning communities in the mathematics classroom: an international literature review. *Pedagogies: an international journal 3*(3), 133-149.