Scaffolding Small Group Interactions

Roberta Hunter
Massey University
<r.hunter@massey.ac.nz>

In the current reform of mathematics classrooms teachers are required to develop discourse communities in which all students have equitable opportunities to engage in productive discourse. The challenge is for teachers to engage students in the mathematics talk across a range of classroom situations. In this paper I address how a teacher used interactional strategies to scaffold participation of her diverse students in small group interactions. I report on the actions the teacher took to shift the patterns of discourse from a disputational form to one in which the students collectively constructed group explanations and justification.

Over recent years significant changes have occurred in how mathematics classrooms are conceptualised as best able to meet the needs of students in the 21st century. An important hallmark of the changes is a vision of students actively engaged in mathematical discourse within classrooms that resemble learning communities (Manouchehri & St John, 2006). In New Zealand, the responsibility falls on teachers to design "learning environments that foster learning conversations and learning partnerships, and where challenges, support, and feedback are readily available" (Ministry of Education, 2006, p. 24). Similarly, the National Council of Teachers of Mathematics (2000) charges teachers with the responsibility to "establish and nurture an environment conducive to learning mathematics through … the conversations they orchestrate" (p. 18). To achieve such learning communities teachers are required to establish ways in which students can engage in multiple forms of interaction. These include whole class discussions and also small co-operative problem solving groups. But, although the use of small interactive groups is promoted in recent New Zealand policy document (Ministry of Education, 2006a) no guidance for teachers is provided for how these should be established (Irwin & Woodward, 2006). Although there is considerable research available that describes the learning that occurs within small groups and the factors that influence the mathematical learning, there appear to be limited studies that have explored the teacher's role in establishing and maintaining effective small co-operative groups. Therefore, the purpose of this paper is to outline how two teachers created and maintained effective small interactive mathematics groups. The focus of the paper is on the interactional strategies the teacher used and how these resulted in the students engaging socially and cognitively with each others' thinking.

The potential for positive social and cognitive outcomes of working in small groups has been widely recognised (e.g., Blunk, 1998; Mercer & Wegerif, 1999a; Yackel, Cobb, & Wood, 1991). Proponents of collaborative grouping maintain that through providing the individual students with opportunities to articulate their thinking not only do they learn to exchange mathematical ideas – but also they make available their reasoning for examination and critique (Artzt & Yaloz-Femia, 1999; Rojas-Drummond & Zapata, 2004). In addition, through opportunities to explain and justify reasoning, explainers are able to review and reconstruct their mathematical thinking, and extend and build stronger arguments (Whitenack & Yackel, 2002). Other advocates who support teacher use of small groups propose that this structure better meets the needs of the diverse or at-risk students (Baxter, Woodward, Voorhies, & Wong, 2002; Boaler, 2006; Rojas-Drummond & Zapata, 2004; White, 2003). These researchers illustrate that through small group interactions, these students are provided with opportunities to participate in and contribute to productive mathematical discourse without being in the public eye. Within the small supportive groups it is the peers who provide an important forum for the diverse students to develop and extend their mathematical reasoning. In turn, through listening and making sense of their peers' explanations they are able to integrate their reasoning with that of others. Moreover, their peers serve as important models for how they are to recognise and make sense of task demands, make conjectures, and extend their mathematical explanations and justification.

In contrast however, other studies have shown problems that may occur when small group organisation is used by teachers. These relate specifically to the enacted communication patterns and how different members of the group are positioned both socially and academically. For example, Barnes (2005) illustrated how cognitive development of specific individuals was limited by both the communication patterns and social relationships in the small group activity. She reported how specific students within the group were attributed lower status and therefore actively positioned by the others as "outsiders". As a result, their contributions were both interrupted and ignored as irrelevant to progress collective understanding. Likewise, Irwin and Woodward (2006) in a New Zealand Numeracy Project classroom noted the way in which the communication and social relationship patterns limited the collective reasoning of the group. The teacher consistently modelled inquiry discourse patterns when working with the whole class. However, Irwin and Woodward's close examination of groups working independently revealed a predominant use of competitive talk both student to student, and between the boys and girls. Although the teacher had directed them to work cooperatively in these groups she had provided no specific guidance. Similarly, the extensive studies of Mercer and his colleagues (e.g., Mercer & Wegerif, 1999a, 1999b; Rojas-Drummond & Mercer, 2003; Rojas-Drummond & Zapata, 2004) illustrate that without teacher guidance student talk is often of a disputational or cumulative form. In disputational talk the students rather than trying to reach joint agreement work through cyclic assertions and counter-assertions as they struggle for control and status. In the cumulative form a collective view is reached but without evaluative discussion.

Therefore, if students are to engage in productive small group activity teachers need to scaffold specific interactional strategies that support equitable outcomes for all participants. To do this Mercer (2000) promotes the use of a specific programme for teachers to use which he terms "talk lessons". Mercer and his colleagues in a range of studies illustrated how teachers implementing "talk lessons" utilise a number of interactional strategies. These are used to scaffold student participation in mutual inquiry and exploration of the reasoning used by the group members. The teachers use a set of ground rules that emphasise sharing of information, a need for group agreement and responsibility for decisions. But the ground rules also focus on challenge and justification of the collective reasoning. Similarly, Alrø and Skovmose (2002) describe teacher use of an interactional structure they term an "inquiry co-operation model", which aims to engage students in mutual inquiry of open-ended problems. Descriptions of studies that have used this model focus on how the teachers specifically scaffold active listening and identification of varying perspectives of the participants. However, when the reasoning is clarified, it is then subjected to challenge and debate before a collective view is accepted.

Boaler (2006) extends the thinking related to how teachers use interactional strategies to scaffold productive discourse in small groups to include ways teachers have used these with diverse learners. In her research Boaler (2006) examined how teachers used an approach she terms complex instruction. In this approach she outlines the use of heterogeneous grouping and open-ended problems to draw multiple ways to value student contribution. She includes as important group roles for students and responsibility for each others' learning. Within the notion of group responsibility Boaler illustrates the importance of justification and reasoning and the way in which the "teachers carefully prioritised the message that each student had two important responsibilities – both to help someone who asked for help, but also to ask if they needed help" (p. 6). In this model the importance of teacher's high expectations, their affirming effort over ability and their assigning competence is emphasised. Competence is assigned when teachers raise the status of students through public recognition of the intellectual value of their reasoning. Boaler also showed how the diverse students learnt valued learning practices through the teachers explicitly noting which specific actions best supported their learning.

The theoretical framework of this study is derived from a sociocultural perspective. From this perspective mathematical teaching and learning are inherently social and embedded in active participation in communicative reasoning processes (Lerman, 2001). In this environment, students successively gain increased levels of "legitimate peripheral participation" (Lave & Wenger, 1991, p. 53) as they access and participate in productive mathematical discourse.

Research Design

This research reports on one teacher case study from a study that involved four teachers in a one-year collaborative teaching experiment. The study was conducted at a New Zealand urban primary school where students came from predominantly low socio-economic home environments. Students were predominantly of Pacific Nations and New Zealand Maori ethnic groupings with many speaking English as their second language. Based on the results from the New Zealand Numeracy Project Assessment tool (Ministry of Education, 2004) members of the 8-, 9-, and 10-year-old group were achieving at significantly lower numeracy levels than comparable students of similar age grouping in New Zealand schools at the beginning of the study.

Collaborative teaching experiment design (Cobb, 2000) was used in order to direct teacher and researcher attention on the social process of the mathematical discourse, while retaining awareness of the mathematical product of the activity. In recognition of the two central characteristics of teaching experiment design research, the iterative cycles of analysis and an improved process or product, a tentative communication and participation trajectory was used to map the progression of the discourse toward inquiry and to provide focus for the subsequent shifts in participation and communication. For example, after Ava (pseudonym for the teacher) had completed teaching a unit of work that focused on number and before she taught a rational number unit, the types of questions Ava and the students could use and the patterns of interactions anticipated to scaffold a further shift toward inquiry and justification of reasoning were considered and mapped out.

Data collection over one year included three semi-formal teacher interviews, classroom artefacts, field notes, twice-weekly video-captured observations of lessons, diary notes of informal discussions during and after lesson observations, written and recorded teacher reflective statements and teacher recorded reflective analysis of video excerpts. The on-going data collection and analysis maintained a focus on the developing mathematical discourse. This supported the iterative cycles and revision of the interactional strategies. Data analysis occurred chronologically using a grounded approach in which codes, categories, patterns, and themes were created. Through use of a constant comparative method, which involved interplay between the data and theory, trustworthiness was verified and refuted.

Results and Discussion

At the beginning of the study in line with the New Zealand Numeracy Project (Ministry of Education, 2006), Ava regularly used a small group format in which the students were required to construct explanations of their solution strategies. However, examination of the group interactions in the first lesson observations revealed that the students predominantly used either cumulative or disputational talk (Mercer, 2000). For example, a group of three students are solving a fraction problem.

Hinemaia: What I think is five is a quarter of ten.

Candice: Yeah. No but what about …

Helen: You put five in each paddock and then all the five because you have got two paddocks equal ten plus another five will equal ten and ten plus ten will equal twenty. We need a fraction.

Hinemaia: Oh maybe a ten is a half quarter of twenty. Now we need to think more in our mind.

Helen: Well me and you Hinemaia are thinking. All you are doing is sitting and saying yeah true. You are not doing any maths thinking [to Candice]

Candice: Well I am trying to …

Hinemaia: You have got to think there actually [points to her head].

In this discussion the erroneous reasoning was left unexamined. The third member of the group was positioned by the other two in such a way that she was not able to contribute to the discussion. They consistently interrupted or discounted her explanation or questioning. Then they attributed to her a lower social and academic status because they stated that she had not demonstrated “thinking”.

Developing a Shared Perspective in Small Group Interactions

To change the interaction patterns, in the first instance Ava focused on how the students participated together in small group activity. In accord with the trajectory, she placed a focus on their need to engage actively in listening, discussing and making sense of the reasoning used by others. After the students had individual time to think about a solution strategy she directed them:

Ava: You are going to explain how you are going to work it out to your group. They are going to listen. I want you to think about and explain what steps you are doing, each step you are doing, what maths thinking you are using. The others in the group need to listen carefully and stop you and question any time or at any point where they can’t track what you are saying.

Ava emphasised their responsibility to develop understanding of the reasoning from the perspective of each member of the group. She discussed the roles of members in the group and placed particular importance on the need for justification and reasoning to develop a collective view. For example, she observed the students as they worked together and then noting that some members of the group were accepting uncritically the explanations from other group members she instructed them:

Ava: Argue your maths. Explore what other people say. Listen carefully bit by bit and make sense of each bit. Don't just agree. Check it all out first. Ask a lot of questions. Make sure you can make sense that you understand. What's another important thing in working in a group?

Alan: Share your ideas. Don't just say I can do it myself that adds on to teamwork.

Ava: That's right. We do need to use each other's thinking … because we are very supportive and that's the only way everyone will learn. So we have to be discussing, talking, questioning, and asking for clarification. Whatever it takes to clarify what you understand in your mind.

Thus, Ava had emphasised that they were required to understand the reasoning from the perspective of others. In addition, she had outlined their need to question and she had reminded them of their responsibility to respond and clarify their reasoning when questioned by other group members.

To further develop group consensus of their reasoning Ava introduced the use of only one pen and one piece of paper in each group. She also required that every member of the small group could explain to her or to a larger sharing group the collective explanations. This was illustrated when Ava instructed a group before they began work:

Ava: Together you need to know what you're … saying and what you are doing. You may need to use your fractions pieces and lots of different ways to make it make sense to all of you in the group … When it comes to the sharing time you need to be able to explain and justify what you are saying in lots of different ways. We are all going to need to be able to see what you are saying, see your reasons behind your explanations. I am going to ask anybody in the group to explain. So you have to make sure that everybody in the group can explain anything you are asked.

The group explored three different solution strategies and then they discuss which one to provide to the larger group.

Rachel: About this one, it's a bit hard to understand because it was so fast.

Tipani: Okay. The truth is this is the most efficient way. That's a good way. That's a good way. But that's the most efficient.

Rachel: Yeah but that one is the most efficient because it's easier to understand. This is more confusing even if it is the fastest. So let's go with the one we know everyone will understand.

In their discussion they illustrated that they recognised that their responsibility to make their reasoning clear extended to a wider audience. They knew that they needed to consider how their explanation would be understood from the perspective of the listeners.

Ava was aware that different students had different status in her class. Although she focused on their need to consider the reasoning used by all the participants in the group she also actively positioned specific students. For example, after she had observed a shy

Pasifika student making an explanation to the small group she began the large group sharing by asking:

Ava: Aporo do you mind if we kick off with you because you were doing some really good talking and explaining to your group and I think this will be a really good opportunity for you to show your maths thinking.

When Aporo began his explanation in a quiet voice Ava requested that the other students listen closely. Then when another student began to prompt him and he hesitated she told the student:

Ava: He knows. He knows. You don't have to prompt him because he knows where his thinking is going.

As this point Aporo became more confident and completed his explanation using a louder voice and making notated recordings to illustrate his reasoning further. Through her actions and her direct focus on the intellectual value of Aporo's reasoning, Ava had shifted Aporo's social status within the group. She had positioned him so that he had a voice and confidence to use it.

Learning Ways to Disagree and Challenge Politely

Engaging in questioning and inquiry involved considerable challenge to how many of these diverse students had experienced mathematics previously. Therefore, in accord with the trajectory Ava introduced the use of open-ended tasks and problems. These supported the notion that there were multiple ways the students in their small groups could develop and support each other in the construction of explanatory reasoning and justification. Ava explicitly directed their attention to the many different roles the individuals in the group could take in developing the collective reasoning. She affirmed those students who preferred to begin by using concrete materials and drawings. She emphasised that these actions were part of the different ways all the members contributed to group activity. She also often stopped groups shortly after they had begun working together and discussed with them the different ways they had selected to approach the problems. She would explore with them where their reasoning had begun and what actions and ideas the different group members were working with. Alternatively, she would join a group and listen closely and then question a group member quietly:

Ava: So how are you going Ruru? How are you going with your thinking?

Ruru: I am trying to explain it to them.

Ava: You are trying to explain it. Are they listening?

Hinemoa: No. He just said he already knows that they have eaten the same.

Ava: That's all right. He has started you thinking. Now you need to listen to him. He needs to explain step by step.

Ruru: I don't know yet.

In response, Ava affirmed the role he had played in beginning the development of a group solution strategy.

Ava: That's fine. You have started the thinking. Now other people in the group may have other ways of thinking and explaining.

Hinemoa: I think he is wrong because if they both ate the same. But I am not sure. He said they both ate the same but there's only five. There's two fifths there and you have to cut it in half but you can't cut it in half if you have only five.

Aroha: Yes you could if you actually had a half, if you halved the piece.

Ava, listening to the students' discussion, realised that they were engaging with the thinking Ruru began. She then advanced their reasoning by suggesting the use of an alternative means to clarify their ideas.

Ava: What about drawing what you mean?

Aroha: You could go like that. So that halved that piece in the middle so it would be equal [Draws a cakes and then uses her hand to show a half of a shape and a half again].

Ava's actions in the group had shown them that she valued the multiple ways the group members contributed to the group discussion. The students were learning what Boaler (2006) terms multidimensionality, which highlights that "when there are many ways to be successful, many more students are successful" (p. 3). These students were learning that every contribution they made in their groups provided a valid basis for open discussion and a way to progress the group reasoning.

Ava recognised the social and academic risks students took when they disagreed or challenged the reasoning of others. Therefore she carefully structured ways in which the students in their small groups could approach disagreement and challenge. She would watch the students working together in their small groups and then she would ask specific members if they agreed or disagreed with the reasoning being used. She also consistently required that they provide justification for the specific stance they took. As the groups worked together she reminded them:

Ava: Please feel free to say if you do not agree with what someone else has said. You can say that as long as you say it in an okay sort of way. If you don't agree then a suggestion could be that you might say I don't actually agree with you. Could you show that to me? Could you perhaps write it in numbers? Could you draw something to show that idea to me? That's fine because sometimes when you go over and you do that again you think…oh maybe that wasn't quite right and that's fine. That's okay.

Ava would also place herself as a participant in small group activity and model behaviour that tuned the students into becoming more aware of other participants responses revealed in their body language. She would actively prompt and probe for agreement or disagreement when she noted a frown on participants' faces or a querying shift in their bodies. Her active prompts to voice agreement and disagreement were appropriated by the students when they worked independently. They would explain a solution strategy step by step, watching the other group members carefully. When they saw a hesitant or querying look on a peer's face the explainer would halt the explanation and respond by asking:

Rachel: Tama you look confused? Do you need to ask some questions?

Tama: Well three times three? Isn't it three plus three plus three not the times way?

As a result the students took ownership of their reasoning and they recognised their collective responsibility to ensure that it was understood by all group members. Justification and reasoning had become key components of the collaborative interactional strategies the groups used.

Learning the Practices of Mathematics

Ava consistently interacted with the students, exploring and discussing with them interactions that supported them learning the practices of mathematics. When she heard a student persistently questioning another group member's reasoning she stopped the group and told them:

Ava: One thing I will say about you Jo you are never scared to question. It makes other people start to question what their own thinking is.

Her description affirmed that a sound learning practice was to question until sense-making was achieved. At another time she stopped the groups to focus attention on the way in which a student had persistently worked at a problem.

Ava: Did you see that? Rona has been working this way and that way. She went down one path and then down another and she never gave up. That's how you learn, thinking and rethinking, starting and starting again and that's okay, that's how you learn.

Ava had used Rona as a model to illustrate to the students that both persistence and effort were valued attributes in mathematics.

Ava wanted the students to examine the reasoning used by the members of their small group closely. In the first instance she would halt a group when she heard a students ask a question that clarified or challenged the reasoning. Or she would ask the students to formulate questions they could ask each other when they approached her for support. However, she knew that they required more scaffolds than her directives to them to question and challenge. Therefore, using the trajectory as a guide, at regular intervals during the year she introduced a different set of questions and prompts. She began with a set of questions that the students could use to elicit more information about mathematical explanations. They included such questions as "what", "where", "is that", "can you show us", "explain what you did". When the students were using these ably she introduced a range of questions that challenged and drew justification of the reasoning other group members used. The questions included "but how do you know it works", "why", "how", "convince us", "so what happens if", "are you sure". The final set of questions she introduced, were designed to draw generalisations. They included "so why is it", "does it always work", "does it work for all numbers", "is it always true", "why does that happen", "is there a different way". She actively modelled the use of these questions and prompted the students to use them as she participated in their small groups. She also displayed them on charts on the wall. When she heard a student use a different form of one of the questions she would halt the group and draw their attention to the question and how it was being used. Then she would add it to the wall chart.

Conclusions and Implications

Within the teaching design experiment the communication and participation trajectory was used successively to review and map out the interactional strategies Ava used to scaffold the students in small group interactions. Over the year, Ava implemented a wide range of interactional strategies that focused the students' attention on the development of a collective view. Many of the interactional strategies that Ava emphasised matched those described by Boaler (2006). These included the importance of open-ended problems and tasks that supported a range of ways to contribute to the group processes. However, of key importance in the development of productive group processes and discourse in Ava's classroom was the emphasis she placed on group responsibility to each other. As Boaler (2006) described, central to the group responsibility was the requirement for the students to justify and provide valid reasoning for their solution strategies.

The observations of group processes at the start of the study confirmed what Mercer (2000) and his colleagues describe. The students encountered many difficulties when asked to participate in small groups. As Mercer describes, the students predominantly used unproductive talk and poor social behaviour. Ava employed specific strategies to position her diverse students. She scaffolded them to take a stance and agree or disagree with the reasoning and she also ensured that they were viewed as academically competent. Her actions are similar to those described by other researchers including White (2003) and Boaler (2006).

The findings of this research reveal that the consistent attention Ava directed toward developing different forms of questioning scaffolded the students' skills to examine and analyse the reasoning group members used. Although she did not use specific programmes like those described by Mercer (2000) or Alrø and Skovsmose (2002), her carefully considered scaffolding of student interactions and questioning paralleled their work.

Effecting change in the small group interactions was a lengthy process. It required on-going attention by Ava of the discourse used in the groups. It also required her active participation as a model of the interaction patterns in the group and her highlighting student behaviour to demonstrate valued interaction patterns. Further research is needed to examine other factors that are important in enacting and maintaining diverse learners' use of productive discourse.

References

Alrø, H., & Skovsmose, O. (2002). *Dialogue and learning in mathematics education: Intention, reflection, critique.* Dordrecht, The Netherlands: Kluwer Academic Publishers.

Artzt, A. F., & Yaloz-Femia, S. (1999). Mathematical reasoning during small-group problem solving. In L. V. Stiff & F. R. Curcio (Eds.), *Developing mathematical reasoning K-12: 1999 yearbook* (pp. 115-126). Reston, VA: National Council of Teachers of Mathematics

Barnes, M. (2005). 'Outsiders' in a collaborative learning classroom. In M. Goos, C. Kanes, & R. Brown (Eds.), *Mathematics education and society* (Proceedings of the 4th International Mathematics Education and Society conference, pp. 58-68). Brisbane: Griffith University.

Baxter, J., Woodward, J., Voorhies, & Wong, J. (2002). We talk about it, but do they get it? *Learning Disabilities Research and Practice, 17*(3), 173-185.

Blunk, M. L. (1998). Teacher talk about how to talk in small groups. In M. Lampert, & M. L. Blunk (Eds), *Talking mathematics in school* (pp. 190-213). Cambridge: Cambridge University Press.

Boaler, J. (2006). "Opening our ideas": How a detracked mathematics approach promoted respect, responsibility, and high achievement. *Theory into Practice, 45*(1), 1-11.

Cobb, P. (2000). Conducting teaching experiments in collaboration with teachers. In A. Kelly, & R. Lesh (Eds), *Handbook of Research Design in Mathematics and Science* (pp. 307-333). Mahwah, NJ: Lawrence Erlbaum Associates.

Irwin, K., & Woodward, J. (2006). Advancing Pasifika students' mathematical thinking. In F.Ell, J. Higgins, K. C. Irwin, G. Thomas, T. Trinick, & J. Young-Loveridge (Eds.), *Findings from the New Zealand numeracy development projects* (pp. 80-90). Wellington: Ministry of Education.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation.* New York: Cambridge University Press.

Lerman, S. (2001). Cultural discursive psychology: A sociocultural approach to studying the teaching and learning of mathematics. *Educational Studies in Mathematics,* 46, 87-113.

Manouchehri, A., & St John, D. (2006). From classroom discussions to group discourse. *Mathematics Teacher, 99*(8), 544-552.

Mercer, N. (2000). *Words & Minds*. London: Routledge.

Mercer, N., & Wegerif, R. (1999a). Is "exploratory talk" productive talk? In K. Littleton & P. Light (Eds.), *Learning with computers* (pp. 79-101). London: Routledge.
Mercer, N., & Wegerif, R. (1999b). Children's talk and the development of reasoning in the classroom. *British Educational Research Journal, 25*(1), 95-112.
Ministry of Education. (2004), *Book 2: The diagnostic interview.* Wellington: Ministry of Education.
Ministry of Education. (2006), *Book 3: Getting started*. Wellington: Ministry of Education.
Ministry of Education, (2006a). *The New Zealand curriculum draft for consultation 2006*. Wellington: Learning Media.
National Council of Teachers of Mathematics, (2000). *Principles and Standards for School Mathematics.* Reston, VA: Author.
Rojas-Drummond, S., & Mercer, N. (2003). Scaffolding the development of effective collaboration and learning. *International Journal of Educational Research, 39(1-2)*, 99-111.
Rojas-Drummond, S., & Zapata, M. (2004). Exploratory talk, argumentation and reasoning in Mexican primary school children. *Language and Education, 18(6)*, 539-557.
White, D. Y. (2003). Promoting productive mathematical classroom discourse with diverse students. *The Journal of Mathematical Behaviour, 22*(1), 37-53.
Whitenack, J., & Yackel, E. (2002). Making mathematical arguments in primary grades: the importance of explaining and justifying ideas. *Teaching Children Mathematics, 8(*9), 524-528.
Yackel, E., Cobb, P., & Wood, T. (1991). Small-group interactions as a source of learning opportunities in second-grade mathematics. *Journal for Research in Mathematics Education, 22*(5), 390-408.