Fostering Communication Between Students Working Collaboratively: Results From a Practitioner Action Research Study

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As a secondary mathematics teacher, I used practitioner action research to determine effective ways to intervene with students working in groups, with the goal of improving their communication. Utilising transcripts of group interactions and teacher interventions, field notes, and student feedback, I discovered ten different issues that prevent students from communicating effectively and developed ways in which I could intervene with the students, when these issues occurred, through questions or comments. Readers may identify with the issues presented in this article and be able to use the interventions to help improve discourse between their students working in groups.

Keywords: practitioner action research • discourse • teacher interventions • collaborative learning • geometry

Discourse During Group Work

Standards for teaching mathematics (e.g., Australian Association of Mathematics Teachers [AAMT], 2006; National Council of Teachers of Mathematics [NCTM], 2000) stress the importance of discourse in the classroom. The mathematics curriculum should help all students to refine their thinking through communication, communicate their thinking to both teachers and fellow students, assess the thinking of others, and use mathematical language to articulate their ideas (NCTM, 2000). One of the key methods used to promote mathematical discourse is to have the students work collaboratively (Artzt, 1996; Cohen, 1994; Webb, Farivar, & Mastergeorge, 2002; Yackel, Cobb, & Wood, 1991).

Since starting teaching secondary school mathematics, I have arranged my students in groups. In one school, I had a conversation with one of my colleagues that went something like the following.

Colleague: When I walked by your classroom the other day, I noticed that you had your students in groups.

Author: Yeah.

Colleague: Do you do that often?

Author: Yes. I have them in groups every day.

Colleague: I tried groups once and it just didn't work. The students were not doing their work—it felt like chaos.

When a teacher uses cooperative groups for the first time, the implementation will probably be far from seamless. In addition to being a new experience for the teacher, the strategy is potentially novel for the students. They might not understand their role in the learning process which may manifest in behaviours such as not working at all, working individually, or allowing one student to dominate the conversation. What can teachers do in these situations to foster communication between students? In particular, what can teachers do to help students "structure logical chains of thought, express themselves coherently and clearly, listen to the ideas of others" (NCTM, 2000, pp. 348–349) and evaluate those ideas in their interactions with their group members?

As a practising secondary mathematics teacher, I had the opportunity to explore the aforementioned questions using practitioner action research, resulting in the discovery of ten issues that arise when students work collaboratively and the development of ways in which I could interact with the students through questions or comments (i.e., interventions) when issues occurred.

Review of the Literature

Although benefits of collaborative learning such as improved attitude, engagement, problem solving, and achievement, have been well documented (Dees, 1991; Leikin & Zaslavsky, 1997; Vaughn, 2002; Whicker, Bol, & Nunnery, 1997), simply putting students in small groups is not enough to improve mathematical thinking (Kramarski & Mevarech, 2003; Mevarech, 1999). Webb (1989, 1991) found that the quality of the discourse in collaborative groups is linked to the attainment of mathematical understanding.

The work of Vygotsky (1986) supports the idea of the social construction of knowledge; that is, students grow in their own thinking through discourse with others. By interacting with a person with greater cognitive capabilities, such as a teacher or a more advanced peer, students are able to move beyond their present comprehension level (Vygotsky, 1978). The focus is on a student's potential level of understanding rather than the student's current abilities with the distance between the two called the Zone of Proximal Development (ZPD). Vygotsky broadened the concept of the ZPD to include peers of equal abilities working together an approach which Goos, Galbraith, and Renshaw (2002) called "collaborative ZPD" (p. 196). When students collaborate, they are able to solve problems that exceed their present capabilities.

Vygotsky (1978) further posited that by engaging in cooperative experiences, students will eventually be capable of working out the problems individually:

> Learning awakens a variety of internal developmental processes that are able to operate only when the child is interacting with people in his environment and in cooperation with his peers. Once these processes are internalized, they become part of the child's independent developmental achievement. (p. 90)

Lambdin (1993) claimed that the increase in independent problem-solving abilities could signify that the cognitive monitoring offered by a peer when working collaboratively was internalised to self-regulation when working individually.

Cognitive monitoring, self-regulation, and metacognition, have been the focus of several studies (Artzt & Armour-Thomas, 1992; Garofalo & Lester, 1985; Goos et al., 2002; Lambdin, 1993; Schoenfeld, 1987). In these studies, transcripts of students working in small groups were analysed to determine the type of interactions that resulted in successful problem solving. Students who were not successful made inferior metacognitive decisions and did not critically evaluate each other's reasoning. On the other hand, students who were successful appraised the thinking of their group members, eliminating impractical strategies and exploring effective methods. Although the results of these studies delineate the importance of cognitive monitoring and metacognitive skills, the teacher's role in developing students' dialogue was not addressed. Since the problem-solving episodes were restricted to interactions between students, neither instructional strategies nor teacher interventions were examined.

Several studies have investigated the effects of direct instructional strategies that teach students to use metacognitive questions while working on mathematical tasks (Kramarski & Mevarech, 2003; Kramarski, Mevarech, & Arami, 2002; Mevarech & Kramarski, 2003; Mevarech, 1999). Mevarech and Kramarski (1997) designed the *IMPROVE* method, which stresses reflective discourse between students working cooperatively. Their framework consisted of four types of metacognitive questions that included understanding the problem, making connections with previous knowledge, using appropriate strategies, and reflecting on the solution process. Overall, students who were trained to regulate their thinking and the thinking of their group members performed better on mathematical tasks than students who did not receive the training.

Specifically, Kramarski and Mevarech (2003) found that students who worked cooperatively and received metacognitive training performed better than students who worked individually and received metacognitive training and students who worked cooperatively or individually without metacognitive training. These results held true when comparing metacognitive training with providing students with worked out examples (Mevarech & Kramarski, 2003) and comparing metacognitive training with direct instruction on strategy (Mevarech, 1999). In addition, students of both lower and higher ability performed better on authentic tasks (no algorithm) and standard tasks when they worked collaboratively and received metacognitive training (Kramarski et al., 2002).

While the studies were being conducted, the teachers did assist the students when they were working in small groups. In two of the studies (Mevarech, 1999; Mevarech & Kramarski, 2003), the teacher worked as an additional group member with one group for ten to fifteen minutes. In the other two studies (Kramarski et al., 2002; Kramarski & Mevarech, 2003), the teacher using the metacognitive training method modelled the use of metacognitive questions when helping the students. Although the teachers did interact with the students, the intent of the studies was to compare instructional methods, not teacher interventions.

In addition to choosing an instructional method when using collaborative groups, a teacher also interacts with the groups while they are working on problems, influencing the subsequent student discourse. The *Standards for Excellence in Teaching Mathematics in Australian Schools* (AAMT, 2006) specifically address teachers' roles in interacting with students: "Their [excellent] teaching promotes, expects and supports creative thinking, mathematical risk-taking in finding and explaining solutions, *and involves strategic intervention and provision of appropriate assistance*" (AAMT, 2006, p. 4, emphasis added). However, very few studies (e.g., Brodie, 2000; Dekker & Elshout-Mohr, 2004; Ding, Li, Piccolo, & Kulm, 2007) have specifically focused on the issue of effective methods of teacher intervention with small groups.

Using qualitative methods, Brodie (2000) investigated the interactions of one teacher with one group of three students. The teacher's principal means of intervening was to present the students with counter arguments to encourage the students to reconsider their thinking. One of the challenges that the teacher encountered is that she was not present for all of the students' interactions about a problem. Therefore, she was not necessarily able to attend to significant problems with the students' processing of the problem. Based on her findings, Brodie proposed, but did not evaluate, additional alternative teacher interventions such as leading students away from misconceptions, helping students to make connections with what they have previously learned, and centring the discussion about the reasons why a particular strategy was not successful.

In the context of a larger study, Ding et al. (2007) evaluated teacher interventions in videotapes of the same single lesson taught by six different teachers. The researchers coded characteristics (length, frequency, and choice) and examined the quality (learning objectives as the focal point, fostering student thinking, and promoting student-to-student discourse) of teacher interventions. The teachers encountered challenges in asking questions that reflected the students' thinking, supporting the development of multiple approaches to solving problems, using student errors as a learning opportunity, and encouraging peer interaction. Since the data were a snapshot of the six teachers' practices, the objective of this research was not to offer and evaluate teacher interventions. However, since the findings highlighted teachers' difficulties, especially in promoting discourse between students, the need for the current research is supported.

The work of Dekker and Elshout-Mohr (2004), who compared *product help* and *process help*, served as the inspiration for the present study. In a product help model, the teacher answers questions or provides hints related to the mathematical content of a problem. In the process help model, the teacher focuses on helping the students communicate with each other. Ding et al. (2007) observed that

> Some teachers are good at guiding and promoting students' thinking, but they may not often encourage students to discuss ideas with each other [process help], preferring instead to give immediate answers [product help]. Thus, teachers are often so busy interacting with many individual students that they neglect peer interaction. (p. 172)

Dekker and Elshout-Mohr (2004) found that the students who received process help outperformed the students who received product help on a post-test. However, the researchers did not elaborate on how the instructor offered the process help. Therefore, the purpose of the present study was to examine my interactions with students working collaboratively, in order to identify interventions that foster communication between students working in groups.

Methods

As previously mentioned, at the time of the research, I was a secondary mathematics teacher. I chose to study my own practice over a three-month period utilising practitioner action research.

> In the field of education, the term *action research* connotes "insider" research done by practitioners using their own site (classroom, institution, school district, community) as the focus of their study. It is a reflective process but it is different from isolated, spontaneous reflection in that it is deliberately and systematically undertaken and generally requires that some form of evidence be presented to support assertions. (Anderson, Herr, & Nihlen, 2007, p. 2)

Teachers often reflect informally on a lesson. Practitioner action research, on the other hand, requires a more intentional plan of reflection which includes identifying a question of interest and planning how to answer it; considering who will be involved, what data will be collected, and how the data will be analysed.

The high school in this study was located in the northeast of the USA. A college preparatory geometry class was selected to take part in the research using purposive sampling (Anderson, Herr, & Nihlen, 2007), which involves selecting participants based on their relevance with respect to the purpose of the study. The sixteen students, aged 15–16, were placed in four groups of four students each. The results of an initial survey indicated that none of the students had worked in groups on a regular basis in their previous mathematics courses. In addition, when describing their prior in-class experiences, the students acknowledged that they were not actively engaged in the learning. Hence, the backgrounds of these students were relevant to the goal of identifying ways in which a teacher can foster and improve communication between students working collaboratively.

Practitioner action research is a reflective process that "requires that some form of evidence be presented to support assertions" (Anderson, Herr, & Nihlen, 2007, p. 2). The evidence is data, and several data sources were utilised. Small-group work was a portion of every class meeting. For each group of four, student discussions were audio-taped when I was helping the group as well as when they were working without my assistance. One group—whom I shall call Beth, Laura, Ellen, and Kevin—was randomly chosen for a detailed analysis, and these tapes were transcribed and analysed. I also wrote field notes after each class session, documenting what had occurred. Further, students shared their views by contributing to two audio-taped whole-class discussions, based on questions such as "What could the teacher do if (a) one person does all of the work or (b) someone is not being helped?" They also responded to six questionnaires (e.g., "List five different questions that you can ask your groups members if you are struggling on a problem"). These discussions and questionnaires occurred approximately every one and one half weeks and had various purposes such as describing mathematics classroom experiences, evaluating my interventions, and reflecting upon their communication.

When analysing the data, I outlined the different issues that arose with the student communication; expanded upon the framework of Dekker and Elshout-Mohr (1998, 2004) to analyse the students' communication; and created, evaluated, and refined the interventions by repeated cycles of planning, acting, observing, and reflecting—an integral aspect of practitioner action research. I had expected to attempt and assess interventions immediately. However, I discovered that various issues occurred with the student interactions based on factors such as the make-up of a group or the type of activity. Therefore, in order to develop appropriate interventions, I had to first identify issues that hindered effective communication between group members. Using the constant comparative method (Glaser & Strauss, 1967), I coded the issues appearing in the transcribed group interactions and field notes comparing new codes with previously established codes. Ultimately, emerging from the data analysis were ten issues organised into three categories (promoting communication, quality of communication, and socio-cultural norms—see Tables 2, 3, and 4). The issues in the first category, *Promoting Communication*, concern a lack of communication between all students in a group. The issues in the second category, *Quality of Communication*, reflect poor communication patterns. The issues in the third category, *Socio-cultural Norms*, pertain to norms that impede student learning.

While classifying these issues, I needed a means to assess student interactions so that I could determine their strengths and weaknesses as well as any changes in their communication over the duration of the study. I built upon the existing framework of Dekker and Elshout-Mohr (1998) for analysing student communication. Since I was specifically interested in the students exercising cognitive monitoring, I used a framework developed by Dekker and Elshout-Mohr (1998), which consisted of the first four question-response pairs in Table 1. As I analysed the student communication with the pre-set codes (question-response pairs 1 through 4), I discovered other interactions that I coded using the constant comparative method and added to the original framework (question-response pairs 5 to 8). Question-response pairs 5 and 6, also regulating activities, reflect situations when a student invites a fellow group member to assess his/her work (number 5), and a student suggests either an initial strategy to start the problem-solving process or an alternative strategy when the current approach is not successful (number 6). Although question-response pairs 7 and 8 are not regulating activities, I chose to include them because they were a common interaction between the students, and they are examples of students asking each other questions rather than looking to me for answers. Content questions refer to subject matter that the students had previously learned, and clarification questions are about the task instructions or basic mathematical calculations.

Table 1
Framework Used to Analyse Students' Communication

Question/Comment	Response
1. A asks B to show work	1. B shows own work
2. A asks B to explain work	2. B explains own work
3. A criticises B's work	3. B justifies own work
4. A rejects B's justification	4. B reconstructs own work
5. A asks B to evaluate work	5. B evaluates A's work
6. A suggests a strategy to the group	6. The group tries the strategy
7. A asks B a content question	7. B answers A's question
8. A asks B a clarification question	8. B answers A's question

After identifying the issues with the student communication and developing the communication framework, I was able to create, evaluate, and refine teacher interventions. While analysing the earlier transcripts of my interactions with the students, I had noticed two different communication patterns. In the first, I only communicated with one of the group members, generally asking closed content questions. In the second, in response to my intervention, the students had a discussion between each other. These initial observations reflect the different outcomes of product help and process help, respectively, as described by Dekker and Elshout-Mohr (2004).

Since I wanted to promote student-to-student discourse, I created an initial list of process help interventions for each issue. I then tried the interventions and evaluated the students' communication when I was and was not present with the group. In particular, I wanted interventions to initiate the second communication pattern as well as to model and promote the use of the questions/comments and corresponding responses outlined in Table 1. The presence, or lack thereof, of these communication patterns, in conjunction with my field note observations and student responses from the whole-class discussions and questionnaires, served as evidence of whether the teacher interventions were successful in fostering student communication.

Based on this analysis, I revised each intervention, repeating the process as many times as necessary. Different interventions were being used and altered simultaneously because various issues happened throughout the research period. This progression highlights the idea that transforming one's practice is not a discrete event as indicated by my colleague in the opening dialogue: bringing about change is an ongoing reflective process.

Findings

The following sections describe each issue and the corresponding interventions developed for each category. There is some overlap of the interventions for the different issues, and I include example dialogue of a representative sample of the interventions, underscoring their evolutionary development. Since multiple occurrences of interventions and student responses informed decisions made, the sample interactions are typical instances from the data. In the closing section, I demonstrate how the students' communication improved through the use of the interventions.

Promoting Communication

The first category pertains to initiating communication between the students. The particular issues (Table 2) vary from all or some of the students not communicating and/or not partaking in the mathematical tasks.

Table 2
Issues and Corresponding Interventions for the Promoting Communication Category

Category/Issue	Intervention
Promoting Communication	
Cannot work without teacher or dominant student	What are your questions? Redirecting questions to group.
	Directing explanations to group members.
	Refer to other resources.
Help/leave/silence	Leave group with a task.
	Follow-up on progress.
Own zones	Redirecting questions.
	Encourage individual work then comparison of strategies.
Non-participating student	Explain what has been done.
	Ask another student to explain or restate in own words.
	Answer another student's question.

Cannot work without the teacher or dominant student. In this issue, the students either sit silently, not doing any work, or engage in off-task communication if the teacher or dominant student is not present. There are four interventions that were tried when students could not work without the teacher or the dominant student. First, I asked the group members to clarify their confusion by stating the specific questions that they have. I was asking the students to move beyond just saying, "I am confused", to pinpointing the specific areas that are hindering their progress in solving the problem. When students asked me a specific question, I redirected those questions to the group. For example, when the students were determining the sum of the exterior angles of a polygon, Beth asked:

Beth:	Do you have to add them or multiply them together?
Teacher:	What do you guys think?
Kevin:	360.
Laura:	Well, you have to add the three of them, right?
Beth:	Okay, so that will be 360.

When a student responded to the question(s) asked by a group member, the explanation needed to be directed to the other group members. The result of these interventions, which can potentially occur in sequence, was a discussion about a question that was asked by a group member. The fourth intervention was to refer students to other resources, such as the definitions, conjectures, or handouts that we had previously discussed in class as well as teacher-provided hints for the completion of the current problem. If students had questions that no one in the group could immediately answer, I wanted them to consider using the resources at hand.

Help/leave/silence. This second issue occurred when working with a group to get the group members to communicate about a particular problem, but when I left the group, the students either stopped communicating or engaged in off-topic conversations. I commented on this issue in my field notes. The only time that this particular group talked was when I was there helping them. This realisation challenged my perceptions of what the groups do when I am not there, as I had assumed that they continued talking when I left them to help another group.

There were two interventions tried and modified to address the help/leave/silence issue. The first was to give the group members a task, but even if the students completed the charge, there was often no communication about their work so I amended this task to have two components. Not only did I ask the students to work on a particular problem, but I also requested that they communicate about what they had done. For example, after helping two students discover the distinction between convex and concave polygons, they were left the following instructions:

Teacher:	So why don't you each try to write it [explanation of your findings]? And then we can compare what you wrote, and see.

The second intervention followed from the first. After giving the group a task, I later returned to the group to follow up on their progress with both parts of the task: completion of and communication about the problem.

Own zones. The third issue in this category is slightly different from the previous two. It is not the case that the students are not doing the work or cannot approach the task, as they are all engaged with the problem; but they are working individually and not interacting with each other. When this issue arose, students often directed their questions to me instead of a peer. As I did with the *Cannot Work without the Teacher/Dominant Student* issue, I redirected the question to the other group members. However, in this situation, the intervention was not successful. I had to interrupt the other students in the midst of their work, which prevented them from seriously considering the question at hand. I tried a different intervention letting the students initially work alone then approaching them when they were almost finished with the task.

For instance, when the students were solving several problems that introduced the idea of an indirect argument, I approached the group.

Teacher: Did you guys compare your answers?

Laura: Well, we came up with them together.

Teacher: Oh, you did.

Laura: We all wrote it individually.

Teacher: What did you guys come up with?

Laura: Well, we said …

After prompting, three of the students explained what they wrote. Even though they had worked together initially, their explanations varied slightly. When I asked students to compare and contrast their methods and answers, the students began assessing each other's work.

Non-participatory student. The final issue in this category was the non-participatory student who was not participating verbally in the discussion between the other group members. The interventions tried depended on the reason why the student was not interacting. By asking the non-participating student to explain what has been done, I was able to assess whether the student understood what the other group members were discussing. In the first whole-class discussion, one of the students made this suggestion: "I think that people who have nothing [should] try to talk about it: explain it. That way you'd know if they don't understand."

When a non-participating student did not grasp the content about which the other group members were talking, another student was asked to describe the group's work thus far. In order to evaluate whether the non-participating student understood the explanation, the student was asked to recount what the other said. For instance, by using the first intervention, I discovered that Beth was having difficulty finding the missing side lengths of similar figures. After her group members explained two possible strategies, the follow-up intervention was used:

Teacher: So, now Beth, what would you do to figure out z?

Beth:	Do 22 divided by 2, and then multiply that by three-fifths … I don't know.
Kevin:	22 …
Beth:	Can you put it in a fraction?
Kevin:	Or Laura's way: 22 times 3 divided by 5.

Beth's response indicated that she still held misconceptions, and Kevin addressed her questions.

The third intervention dealt with the situation when a non-participatory student was completing the problem but not communicating with the group. In this case, the non-participatory student was encouraged to help the other students in the group by answering their questions.

Quality of Communication

After the students have started to interact with each other as a result of the interventions above, the goal of the *Quality of Communication* interventions (see Table 3) is to enhance that communication. In particular, the interventions were designed to foster the interactions outlined in the communication framework outlined in Table 1.

Table 3
Issues and Corresponding Interventions for the Quality of Communication Category

Category/Issue	Intervention
Quality of Communication	
Need appropriate first intervention	Ask what students understand thus far.
	Use errors as opportunity for inquiry.
Student tries to help another student unsuccessfully	Restate in own words.
	Agree with restatement.
Dominant Student	Restate in own words.
	Highlight overlooked idea of another student.

Need for appropriate first intervention. The first issue in this category occurs when a teacher initially intervenes with a group. Often, students initiate teacher interactions by calling the teacher over with a question after hitting a "road block". The impediment to their progress could occur for different reasons, such as the students not knowing the next steps in the solution process/strategy or making an error that they either do or do not recognise. I wanted my initial response to questions to promote their communication but also to give appropriate help.

My first intervention was to ask what understandings the students had up to the point of my arrival. Based on their response, I then made a more informed decision about the support that I gave the group. One of the challenges with this intervention was that the students had a difficult time expressing themselves mathematically. For example, when I approached a group after they had stopped solving a quadratic equation due to an error that they could not identity, I used the first intervention to which the students responded:

Laura: We were working on this one, and then we got... we... so we said that these are supplementary, so we had that, and then we did this, and then we tried to do this, and it just wasn't ...

Teacher: So, what did you … what do you mean by this, when you said that you tried to do this?

Laura: We tried to do the formula, the quadratic formula, but then we got a negative number under it and you …

Kevin: And, you can't square that.

Laura: And, you can't get square root from a negative number.

Instead of giving a detailed explanation using mathematical terms, they said, "We did this, and then we tried to do this, …", but follow-up questions encouraged them to elaborate on their meaning.

The second intervention was used when students made a mistake. Sometimes they had an error in their work and did not realise it, so I did not want them to continue their work based on an incorrect idea. In other situations, the students knew that they made a mistake, but they could not determine where the error occurred. In either case, the challenge was to help the students identify their mistakes. Instead of directly pointing out their error, I asked them to assess their work, evaluate the work of others, or compare their work with that of their other group members. For example, after the students in the previous case explained to me what they had done, I tried to guide them in finding their error.

Teacher: Okay, so can you walk me through? Can one of you … or, all of you guys take turns, whatever, …walk me through what you did with the quadratic formula?

Kevin: Oh, she did, all right. I didn't do it like that. She did, because we were going to say $8x$ by … plus, no, $8x$ plus x^2 equals 180, but then we thought, you know, "How can you do that?" So, she did x^2 plus $8x$ plus 180 equals 0. Then we did the formula, and a equals 1 for x^2, b equals 8, and c if it was 180; and then we tried to do it like that.

Teacher: So, can you … I actually want to step back for one sec, how did you go from saying that these added to 180, to then getting x^2 plus $8x$ plus 180?

Ellen: Well, they're parallels, and alternate interior, and so this one will just equal to this, and this will be equal to that angle.

Teacher:	Okay.
Ellen:	And, this line equals 180, so that's how we got our, like, our formula.
Teacher:	Okay, so can you write that down … write that equation down then? So …
Ellen:	So, 8x plus x^2 equals 180.
Kevin:	When you combine that, because it'll be 8x …
Laura:	And then … and I just remembered like, I remembered us doing problems in that fashion before, so then I just subtracted 180 and put it there.
Teacher:	Okay, so you just said a key word, you subtracted 180, so what does it become?
Beth:	That turns the negative … or like, yeah. Okay.
Teacher:	So, what does the equation become?
Beth:	It becomes x^2 plus 8x minus 180. Oh, okay, that makes more sense.

In response to a whole-class discussion question about how I helped the groups, one group stated, "She made us explain things out loud so we would notice where we're wrong." Communication between the students is promoted by asking them to analyse their mistakes as well as the mistakes of others.

Student unsuccessfully tries to help another student. The second issue happens when a student explains something to one or more students, but they do not understand the explanation. The students often indicate that they comprehend what was said, yet in reality they do not want to admit that they are still confused and ask more questions. Therefore, to assess whether recipients understand, the first intervention was to ask them to restate the explanation in their own words. For instance, after Ellen explained how she found the two roots of a quadratic equation, Beth was asked to explain Ellen's strategy.

Teacher:	What is she doing? Can you explain it?
Beth:	She, since we took the square root away, we're just … Wait, I thought you had to multiply that.
Ellen:	No, it's addition.
Beth:	Oh, you add it. Okay, okay.
Ellen:	In the beginning, there is addition and subtraction.
Beth:	Okay, and then yeah, you just minus. You would divide that, and then you get your answer.

Through Beth's restatement, it became apparent that she had some misconceptions. The second intervention followed from the first. The student that gave the original explanation was then asked to evaluate the restatement to verify whether it reflected what was originally said. In the previous example, the second intervention was not necessary since Ellen corrected Beth's misunderstanding without being prompted.

Dominant student. A group with a student that dominates the conversation led to the final issue, which manifests itself in different ways. A dominant student often leads the discourse. At times, this can be viewed in a positive light if discussion is initiated between the group members, but it can also be negative if the student dictates the interaction at the expense of contributions of other group members. For instance, Laura often dominated the conversation in the group, as demonstrated when the students were asked to solve systems of linear equations.

Laura: What are we doing? Solve each system of equations.

Ellen: Aren't these systems or something?

Laura: Yeah, so you need to …

Ellen: You solve for y and then whatever.

Laura: You solve for y and then you put it in …

Ellen: Isn't there another way to do these?

Laura: Oh, oh! Okay, I know what that is. I know what we're doing here, because it says that y equals …

Kevin: How?

Laura: So you put that in the equation and for y. And then it's made up to 4, 36.

Laura was describing the substitution method of solving systems of equations and overlooked Ellen's question about an alternate strategy. To promote communication between all of the students, two different interventions were utilised. To assess whether the other students understood the dominant student's explanation, as with the Student Unsuccessfully Tries to Help Another Student issue, I asked them to restate what was said in their own words. When I witnessed a suggestion made by another student being ignored, as in the dialogue above, I highlighted that idea.

Teacher: Now, did you, Ellen, did you do …? How did you do your number two?

Ellen: I just did, multiplied each one by the factor to get the equals, like the x and the y's. And then from there, I took one of the equations and solved for one of the numbers, and I got the answer. And then I plugged that into the other equation and then solved for the other variable. I tried that: I plugged them both in to see if it was right.

This intervention serves a dual purpose. First, students can see that there are often multiple strategies that can be used to approach a problem. Second, other students in the group, and especially the dominant student, may realise that all students have valuable ideas to contribute to the group. Later, Laura addressed Ellen about her strategy:

Laura: [to Ellen] I think you do it differently than I do?

Kevin: Yeah.

Laura: [to Ellen] How do you do it?

Laura was open to learning about a method that was different from what she did as well as listening to Ellen whose question she had previously ignored.

Socio-Cultural Norms

For one of the questionnaires, the students were asked to respond to "Is the way that this class is conducted different from your Math class last year? If yes, explain how the two classes are different. If no, explain how the two classes are similar." One of the students responded, "I was confused at times because I've always just been told what is what and why." By working collaboratively, I was asking students to alter their perspective about how they can learn mathematics.

Table 4 shows the interventions used to support the change in the socio-cultural norms of the classroom.

Table 4
Issues and Corresponding Interventions for the Socio-Cultural Norms Category

Category/Issue	Intervention
Socio-Cultural Norms	
Rushing to complete task	Compare strategies.
	Evaluate work of others.
Teacher as only resource	Redirect questions to group.
	Ask student to redirect question to group.
	Explain work to others.
	Ask others to evaluate work.
Blindly accepting work of others	Restate in own words.
	Evaluate student's ideas.

Rushing to complete task. In the first issue for this category, the primary goal of the students is to finish a problem regardless of the quality of their work. Rushing to complete a task is demonstrated in two ways. Sometimes, students are not able to complete the problem and do as much as they can until they get stuck. If students do complete the problem, they stop at that point. They are satisfied with having any answer. The first intervention, comparing, led to the second, evaluating. If the students made errors, they needed to compare their work, which involved evaluating their work as well as the work of others. For example, after five minutes of off-task communication, I noticed that the four students had three different answers to a system of equations.

Teacher: So, I want you guys to compare answers to see if you got all the same coordinates.

Laura: Yeah, we've all got it. I am just looking …

Teacher: On the last one? Yeah, so Ellen, I think that you guys have all got different answers on number three, so …

Ellen: I tried it, but negative 19 and 4.

Beth: -19, 4

Teacher: Ellen got two.

Laura: I got 4 and 9.

Teacher: So, it looks like you have the four in common. Let's see if you guys can see what the …

Ellen: Ah! It's 9.

Beth: Yeah.

Ellen: Yeah, I am sure that I did it wrong. I added 28 instead of subtracting it. Oops.

The students need to understand that when they arrive at an answer their work is not done. Or, if the students have an error, once they identify the mistake, they are able to continue solving the problem instead of skipping it. By evaluating and comparing their work, they are considering their understandings and strategies as much as the result.

Teacher as only resource. The second issue occurs when the students view the teacher as the only resource when they have questions. The purpose of their inquiries ranges from content to process to verification. Instead of asking a group member the question, a student views the teacher as the primary source of help. To counter this point of view, I used four different interventions. Instead of answering a student's question, I originally redirected the question to the group. In order to encourage the students to ask questions of each other, I eventually altered the original intervention and requested that the student redirect the question to the other group members.

Kevin: [to Teacher] This, this right here—would have to be 180. Right?

Teacher: Do you want to ask her [Laura]?

Kevin: [to Laura] This equals 180. Right here, this?

Laura: Yeah, because they're not supplementary but because they all are on, … because they're all on one line.

One of the questions that the students often asked me was whether they were correct. To help the students realise that they could ask the others in their group the same question two interventions were employed. The first was to request that the student explain the work to the other students, and then ask them to evaluate the work.

Blindly accepting work of others. If a student blindly accepts the work of others, that student listens to an incorrect explanation and agrees with the statement. The initiation of the communication varies—a student asks the others to explain what they have done or to evaluate his/her work or I ask students to evaluate the work of another. For this issue of accepting the work of others without critiquing it, I tried two interventions. To encourage the students to listen to and understand the work of the other students, they were asked to restate the explanations in their own words. Once they comprehended a student's statement or work, I then wanted them to evaluate the ideas. For instance, when the students were determining how to find the sum of the measures of the interior angles of a polygon, I asked them to evaluate Kevin's (incorrect) work.

Teacher: So what does the hint say?

Laura: Says "Divide each polygon into triangles by drawing all the diagonals from one vertex. Use this to help you determine the sum of the interior angles".

Teacher: So did … with what Kevin did, did he satisfy that hint?

Laura: Yes.

Ellen: Yeah.

Teacher: Read the hint again.

Kevin: Divide each polygon into triangles by drawing all the diagonals from one vertex.

Teacher: Okay, so that is important.

Laura: So you would only take it from one corner.

Beth: Oh, it's only one.

Laura: It's like something there.

Kevin: So that would be two. Two.

Beth: That would only be two triangles …

Ellen: But why would that be two?

Laura: I could be wrong. That could be from one vertex. So, that's to say we pick this one, it would have to be like that.

Kevin: Ah!

In this example, all of the students in the group participated in the evaluation of the work. In addition, Ellen—one of the students who initially blindly accepted the incorrect work— asked for a clarification of the correction.

Changes in Student Communication

The coding of the student communication using the communication framework (Table 1) indicated that the students initially struggled with the regulating activities of evaluating their work and the work of others (question-response pairs 3, 4, and 5 in Table 1). For example, the following dialogue occurred when the students were solving a problem for which they needed to set-up and solve a quadratic equation.

Laura: This is actually … Isn't this always supposed to work? Factoring doesn't always work, but isn't this formula, like, always supposed to work?

Kevin: Yeah, so that shows that you can't do that.

Beth: So we … Are you sure that we have the right formula?

Laura: It's always supposed to work, Kevin. So yes, you can do it, you're just trying to get weird numbers. That's why.

Kevin: No, because you can't square root a negative. Do in your calculator … you can't do it, this says error, you can't square a negative.

Laura: But, but why? Isn't it negative?

Kevin: 64 minus …

Laura: No, I don't understand that. But like, did we do something …

Beth: Yeah, we definitely did something wrong. Did we …?

Laura: Okay, do you guys want to come back to this one?

Despite identifying an error when using the quadratic formula, at no point did the students re-examine their work to attempt to determine where the error occurred.

Over time, the data indicated that the students' ability to assess their work improved. For instance, the following interaction between Beth and Laura occurred when they were constructing different types of segments in triangles.

Beth: So, I am confused. What do I erase in mine? Because I found the midpoints.

Laura: Well, the blue ones, what are these? The blue?

Beth: The …

Laura: These are your medians, right?

Beth: Yeah.

Laura: What are these?

Beth: That was the first one that I made, which was also a median, and that was 90 degrees … straight angle one.

Laura: I think that you need to erase this one, because this line needs to be more like this, to make it an L. Look, does that look, if you were to … Does this and this look like a perfect T to you? Does it look like …?

Beth: Sort of.

Laura: Me too, I can't tell. Wait! Measure it with your protractor and see if it's 90.

In comparison with the previous interaction, the students were discussing strategies to check Beth's work rather than being stifled by errors.

The students often asked each other to evaluate their work (question-response pair 5). However, the response was typically a single-word affirmation regardless of whether the explanation was correct. When the students were asked to explain the difference between two-point and one-point perspective drawings, Laura asked the group if they understood her statements.

Laura: I think that two points would be like one you draw, like average 3-D shapes. What do you think of when you're drawing a 3-D shape? You should see it from literally two perspectives, you know, you see this and you see this.

Beth: Yeah.

Laura: As opposed to if there was this, or something. Do you know what I mean? You're seeing it from the front it would be like that. Do you see what I am saying?

Kevin: Yeah.

Laura: If I am not making any sense, you can tell me. I was just trying to ...

Kevin: Actually, I wasn't paying attention.

Beth and Kevin responded positively even through Kevin ultimately acknowledged that he was not listening. As time evolved, this dynamic changed. For example, Ellen determined an answer to a question and asked the others to evaluate it.

Ellen: So, wouldn't *q* equal 121? … Yeah, wouldn't *q* equal 121?

Kevin: No.

Ellen: Because it's vertical.

Laura: What?

Ellen: It's a vertical … this angle's a vertical line.

Kevin: Yeah, but it equals 81.

Laura: No, because, because this, this equals 121, so you have to find out what this is and subtract from 121, and it's because these two are corresponding and since they're corresponding, it's 40 and then you subtract 40 from 121. Do you see what I am saying?

Instead of simply agreeing with Ellen's incorrect answer, Kevin acknowledged that it was incorrect and Laura justified his response.

Instances of improvement in student communication like the two previous examples occurred regularly about six weeks into the study. These examples illustrate that through persistent use of the teacher interventions the students showed improvement in listening to, processing, and evaluating explanations: critical aspects of working collaboratively.

Discussion

The findings of this study attend to the call made by Ding et al. (2007) to "provide teachers with techniques to effectively address student thinking" (p. 174) while working collaboratively. Some studies have documented struggles teachers have encountered when helping students in groups (e.g., Brodie, 2000; Ding et al., 2007); while another (Dekker and Elshout-Mohr, 2004) connected process help with student achievement, but did not articulate how the process help was provided. The results of this study extend the existing literature by describing specific process help interventions that teachers can use to foster and enhance small-group communication, which in turn supports student learning.

Brodie (2000) studied one intervention, providing counter examples, which was not always successful in supporting the students' thinking. This finding indicates that one intervention does not suffice; and the present study further supports this conclusion. Not only were multiple interventions created and evaluated, but also the use of interventions depended upon the particular issues that arose with a group's communication. After data analysis, the issues fell under three different categories: promoting communication, quality of communication, and socio-cultural norms.

The issues and interventions in the "Promoting communication" category emphasise the importance of first identifying why all or some of the students in a group are not communicating. Are the students unable to engage in a task without the presence of the teacher? Or, are the students partaking in the activity but not sharing their ideas? The different circumstances result in the use of different interventions. Overall, through the interventions, the students figure out their questions, direct those questions to their group members, explain their strategies, and compare their work. Further, leaving a group with a task and following up on the group's progress, as with the *Help/Leave/Silence* and *Own Zones* issues, aligns with previous recommendations (e.g., providing students with time to process the guidance received and monitoring group work) that lead to effective help (Webb, 1989; Webb et al., 2002).

Once students are communicating with each other, the focus of the interventions can shift to addressing the quality of the students' communication. In this study, quality communication was indicated by the presence of interactions outlined in the communication framework (Table 1), and the interventions were designed to help develop these regulating activities. First and foremost, before interacting with a group, a teacher needs to determine what the students understand at that point in order to provide an appropriate first intervention. The teacher in Brodie's (2000) study encountered this challenge, because she was not present for the students' discussion, she did not always help her students successfully. By asking students to explain what they have done so far, a teacher is then able to make an informed choice about intervention. In addition, students gain experience in communicating verbally about the mathematics, and any errors are brought to light. These mistakes then become the focus of the teacher interventions. Ding et al. (2007) described this idea as "errors as opportunity for inquiry" (p. 173). Mistakes are often thought of in a negative way—as flaws in a student's thinking. By changing this perspective, errors are perceived as the catalyst for student investigation.

Two of the question-response pairs in the communication framework (Table 1) involve a student asking a peer for help. Webb et al. (2002) describe a continuum of responses when a student helps another through showing or explaining his or her work, ranging from the lowest level of no response to the highest which involves the recipient explaining the problem. Moreover, responses at the highest level were related positively to achievement. The interventions for the *Student Unsuccessfully Tries to Help Another Student* issue not only fostered the highest level of response but also went one step further by asking the provider of the help to evaluate the restatement of his or her original explanation. In addition to developing a deeper understanding, restating an explanation can also result in the identification of errors. Both purposes are critical when there is a dominant student in a group.

> The point is, where students are accustomed to treating one another as authorities no true dialogue takes place between them, and where there is no true dialogue there can be no true collaborative learning. (Amit & Fried, 2005, p. 161)

Conversely, some students are not viewed as authorities and hence are not integrated into the group discussion by their peers (Amit & Fried, 2005). The intervention of *highlighting an overlooked idea of another student* addresses this issue. In summary, the students are encouraged to value the ideas of all members of a group, share those ideas, listen to others, and ensure that all members understand what is being explained.

Although there is a specific category of issues pertaining to socio-cultural norms, redefining the culture of the classroom was a part of all issues and interventions. In particular, there are several commonalities between the issues in the Quality of Communication and Socio-Cultural Norms categories. For instance, the idea of authority comes into play when students blindly accept the work of another student.

> When students are perceived by their fellow students as knowing the answer to some question they are treated for that instant as an authority, that is, the answer *is accepted and not discussed*". (Amit & Fried, 2005, p. 159, emphasis added)

Similarly, a teacher is often viewed by students as an expert authority (Amit & Fried, 2005). Therefore, the intention of the interventions in this category is to change the students' perspective about learning mathematics; that is, finding an authority who will provide an answer or completing a task with the sole goal of getting any answer. Rather, students construct knowledge collaboratively, and this process of arriving at a solution is valued with both process and solution assessed based on the logic of the mathematics. The interventions, which require critically listening and evaluating what was said, encourage students to share and compare their strategies.

Conclusion

The interactional norms that are established in a mathematics classroom affect what and how students learn (Yackel, Cobb, Wood, Wheatly, & Merkel, 1990). The development of the interventions through the repeated cycles of planning, acting, observing, and reflecting was a process of negotiating social norms through which the students learned how to communicate about the mathematics and what means are valued in learning mathematics (Quebec Fuentes, 2011). Further, students developed an understanding of the mathematics through asking questions, listening to and critiquing explanations, comparing and sharing multiple solution strategies, and clarifying errors. "Opportunities for learning not present in traditional classrooms arise when children are engaged in collaborative activity" (Yackel et al., 1991, p. 401), and the teacher interventions developed in this study support the shared practice of making sense of the mathematics.

The purpose of the present study was to determine ways for teachers to intervene with students working in groups to improve their interactions. The resulting interventions were not mere speculation of what might work but were developed through practice and reflection grounded in data. Provided is a detailed description of the findings from my experiences with one particular class so that readers can view the interventions as suggestions for how to interact with students in similar circumstances.

In particular, ten issues that prevented effective small-group discourse were described. The issues pertain to a lack of communication, poor communication, and norms that hinder learning. For each issue, interventions that promoted and improved student-to-student communication were developed and refined. Although the interventions differ, they model and foster activities such as asking questions, sharing and comparing strategies, listening to explanations, and assessing methods and solutions. With this knowledge, teachers can recognise the issue(s) that exist with a group's interactions and consistently use the appropriate intervention(s) to encourage and improve the quality of discussions in small groups, redefine the classroom norms, and enhance students' mathematical understanding.

The findings of this research can be built upon in several ways. First, the study was conducted in just one geometry class. The issues and corresponding interventions can be further refined and expanded by examining the use of the interventions in other classrooms and in different areas, like algebra. One approach to achieve this would be to incorporate the interventions into pre-service and in-service teacher development and report on the experiences of the teachers employing the interventions. In summary, examining the relationship between the use of the interventions and the mathematical attainment of the students has the potential to strengthen the body of research linking effective student discourse and student learning.

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