Chapter 9

Resolving Differences of Perspective in a VMT Session

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Abstract: According to influential theories of learning, individual learning is most effectively furthered by the resolution of differences—whether the differences are those of cognitive conflict in the individual's mental processes or those of multiple perspectives interacting in group knowledge-building processes. This chapter investigates the methods used by virtual math teams to resolve differences of perspective having to do with the group's approach to working on a problem. A fine-grained analysis of chat interaction shows how participants engage in artful ways to negotiate or produce agreement by using each other's conclusions and appending them to their distinct, seemingly incompatible approaches. Participants negotiate which approach is in use, who is to participate in the unfolding of proffered approaches and in what order competing approaches are to be used. Participants also negotiate how solutions are to be assessed for adequacy and correctness. This interactional process of resolving differences drives the learning activity of the virtual math team by structuring the continuity of the discourse.

Keywords: Negotiation, perspectives, participation, Piaget, Vygotsky, interaction analysis, difference

Learning is Driven by the Resolution of Differences

The fundamental theories of the learning sciences—going back to the classic texts of both Piaget (1990) and Vygotsky (1930/1978)—claim that learning is stimulated

by an optimal level of differences among conflicting perspectives on a topic. Modern versions of learning theory refer to this claim as "cognitive conflict"—in the socio-cognitive psychological tradition focused on individual cognition (Perret-Clermont & Schubauer-Leoni, 1981)—and as the "inter-animation of perspectives"—in the socio-cultural dialogical tradition focused on collaborative small-group cognition (Wegerif, 2007).

While there is widespread agreement on the importance of resolving differences for stimulating learning, there has been little analysis to date of the mechanisms by which differences of approach to topics or problems are resolved. The exploration of such mechanisms requires new qualitative research. It is hard to explore scientifically the resolution of differences in the minds of individuals. However, the resolution of differences within small groups may be observable in traces of their communication and interaction. The VMT Project provides a naturalistic experimental environment that was designed and instrumented to capture the interactions of small groups of students faced with collaborative learning tasks. Moreover, this environment is an online synchronous environment—a type of learning context which has great potential for the future of education, but which is not yet adequately understood (Stahl, 2006).

This chapter will identify excerpts from a VMT session in which multiple, conflicting approaches to problem definition and/or solution are proposed by the participating students. It will analyze these excerpts to determine the methods or mechanisms by which conflicts are resolved in the chat interactions. The findings will contribute to an understanding of the mechanisms by which differences are resolved in this case study. These findings will not only confirm that problem solving in such a context is driven by the resolution of differences or conflicts in approach, but will specify some of the ways in which such resolution takes place.

The analysis of the processes through which differences are resolved will demonstrate that the interaction of the students is driven forward (posting by posting) by the conflict between their different approaches and their attempts to resolve this conflict. A new posting accepts what was proposed by a previous posting and tries to re-situate it in the new poster's perspective. In the end, the group solves its problem as a result of such back-and-forth motion across differences.

Negotiation in Problem Solving

Participants in group problem-solving sessions engage in a number of activities such as framing the problem or problems, discussing and assessing approaches, executing these approaches and assessing their results as part of performing the activity described as a "problem-solving session." Whether the problem solving is done face-to-face or through computer-mediated communication, as long as there are multiple participants with their respective approaches, procedures and assessment methods, there will need to be some degree of negotiation. Negotiation, defined as "a discussion intended to produce agreement" or as "the activity or business of coming to an agreement" is a key activity in most group problem solving.

As a focus of research, negotiation has often been examined under theories of communication. This has certainly been the case in comparisons between face-to-face and computer-mediated negotiation in research built on theories of communication such as the media richness theory and media synchronicity theory. *Media richness theory* attempts to explain how the form and flow of information may impact understanding, especially through the reduction of uncertainty and equivocality (Daft & Lengel, 1986). It proposes that negotiation would be more difficult to conduct, the more impoverished the communication medium is. Consequently, face-to-face negotiation would be described as easier to conduct than computer-mediated negotiation performed through text messages. *Media synchronicity theory* proposes that communication effectiveness is influenced by matching the media capabilities to the needs of the fundamental communication processes, called conveyance and convergence (Dennis & Valacich, 1999). It identifies a set of five media capabilities considered important to group work because these are the capabilities an online environment would require for it to be suitable for the negotiation required for collaborative problem-solving.

Negotiation is studied under theories of learning and under the approaches to learning based on them, as negotiation is seen to be important in the interactions of groups engaged in learning. In the theory of learning called *social constructivism*, knowledge is seen to be socially co-constructed through negotiation before it can be internalized by children (Vygotsky, 1930/1978, p. 90). In the theory of *distributed cognition*, knowledge is co-constructed by interactions among people and their shared artifacts, including prominently by means of negotiation practices that result in establishing common ground for understanding (Stahl, 2006, p. 183). A theory and approach to learning such as *situated learning* views learning in terms of changing relations within the community of practice, where knowledge is negotiated interactively and through co-construction (Lave & Wenger, 1991). In distance education, negotiation brings different people's ideas together, thus making sustained, in-depth knowledge building possible (Wegerif, 2006).

Negotiation is also studied for its role in the dynamics of small problem-solving groups within *socio-cognitive* theory (Beers, Boshuizen & Kirschner, 2003). In such groups, important differences among participants' individual representations converge in a shared representation through negotiation. Prior to negotiating a shared representation to come to a solution, teams need to detect differences in individual representations. Two parts in negotiation are described, a process of negotiation of meaning and a process of negotiation of position.

The Mutual Impact of Computer Support and Negotiation

The field of CSCL is especially interested in negotiation in collaborative learning (Stahl, 2006, ch. 8). The question of how computers may facilitate support for problem-solving is not only a theoretical problem but a practical one as well (Kirschner, Buckingham Shum & Carr, 2003; Koschmann, 1996). The literature includes not only studies on how computer support may affect negotiation but also

how a group engaged in negotiation may use available computer support. Systems may consciously follow particular theories in their design. For example, designs that follow the rubrics of flexible structuring are intended to structure interactions. *Flexible structuring* operationalizes its design approach by (a) providing a restricted set of communicative acts that can be used in the interaction, without necessarily enforcing their use in given contexts, and (b) providing flexible constraints and guidance on the use of certain communicative act sequences in specific dialogue contexts (Baker & Lund, 1997).

Literature associating negotiation and problem-solving is frequently linked with the effort to find how computers may support negotiation. For example, an overview proposed by Lim & Benbasat proposes that "the use of computer support will have much to offer in terms of compensating negotiators with what they lack in conducting rational negotiations, that is, higher information-processing capabilities and capacities" (1993, p. 32). Other studies discuss negotiation in the context of how groups and individuals behave in a computer-mediated collaborative work setting. Thus group activity during which negotiation takes place may be analyzed from three perspectives; namely, (i) a group's performance in reference to other groups, (ii) each member in reference to other members of the group, (iii) the group by itself. Such a study may seek to characterize group and individual behavior in a collaborative setting through a set of attributes which would enable the identification of collaborative activity that leads to negotiation toward a shared understanding (Barros & Verdejo, 2000). Related studies show how computer-mediated communication affects group negotiation. Negotiators' performances in terms of negotiation process and outcome are affected by the communication medium; face-to-face and computer-mediated communication are compared to each other (Rhee et al., 1995). Studies which focus on specific communication tools such as chat, may explore the interaction between the richness of communication (Daft & Lengel, 1986; Kock, 2001; 2004; 2005) and its impact on the recipient of the communication (Spencer & Hiltz, 2003). Conversely, groups engaged in collaborative problem-solving may use the affordances of computers in ways unforeseen by the designers of these affordances.

A Research Challenge

When problem-solving is done face-to-face by a group, participants demonstrate to other participants how they define, understand and solve the problem (Herring, 2001). Participants make visible to each other what, how and when they are thus engaged in problem solving, even if what is demonstrated is incomplete or inaccurate. Making the process visible is necessary to enable other participants to concur, disagree, modify or contribute in some way to the definition, understanding and solution of the problem. In a face-to face situation, making visible may involve both spoken word and physical gesture. When problem-solving is done online, participants see only what the computer application that they are using allows them

to see. Whatever is seen, heard or read by each participant is dependent on the features of the application being used.

Though participants in a synchronous online collaborative problem-solving session make their knowledge visible in order to make it possible to collaborate, there is no a guarantee that it is immediately possible to determine how participants negotiate the definition, understanding and solution of a problem they are solving. Participants may move in and out of negotiation mode seamlessly without being consciously aware that they do so. It is not even known how different their viewpoints are; what is hoped for is that after their problem-solving session, their shared output is greater than the sum of their contributed viewpoints and that they have, as a group, reached greater convergence.

To describe negotiation then means to see how participants produce agreement through the tools available to them. This entails a fine-grained analysis of the postings produced by the participants in the course of their online synchronous problem-solving session. The paucity of research which documents how negotiation is achieved in a collaborative online synchronous problem-solving session is a motivation for this exploratory study to describe negotiation as it is experienced and recognized by a problem-solving group.

In this chapter, we will be investigating negotiation in small-group online interaction. Through a detailed analysis of an excerpt from an online chat among three middle-school students, we will develop a notion of negotiation as the interactive production of agreement within a small group. Such negotiation can include the negotiation of the approach to joint problem solving, negotiation of the sequencing of multiple approaches, the negotiation of contributions to unfolding the approaches and negotiation of changing modes of participation. The analysis of negotiation in this excerpt will indicate how important negotiation is to the accomplishment of collaborative work and will note the peculiarities of such negotiation in a CSCL context.

Data and Methodology

We will describe how participants in a problem-solving session negotiate the definition, understanding and solution of the problem presented to them in the online environment. By using the actual log of an interaction, we seek to understand negotiation by seeing how it proceeds as experienced by students in a setting similar to a collaborative classroom (as opposed to a controlled laboratory). We use a method of analysis developed from conversation analysis (Sacks, 1962/1995; Sacks, Schegloff & Jefferson, 1974). Just as conversation analysis has been used to analyze different aspects of plea bargaining (Maynard, 1984), negotiation in the workplace (Firth, 1995) as well as the discussion and assessment of a theory in a problem-based learning group (Glenn, Koschmann & Conlee, 1999), a method based on it can be used to analyze negotiation in chat. At face value, chat seems similar to conversation (O'Neill & Martin, 2003; Zitzen & Stein, 2004), but is different from it in important ways (van Bruggen, Kirschner & Jochems, 2002; Vronay, Smith & Drucker, 1999).

Through this method, we describe how the chat participants initiate negotiation, recognize each other's contributions and negotiate how each other's contributions contribute to a solution, and how a solution is negotiated.

This analysis will be conducted through a description of the interaction of the participants as they conduct their negotiation in the course of their online synchronous mathematics problem-solving and engage in the "members" methods for making those same activities "visibly-rational-and-reportable-for-all-practical purposes, i.e., 'accountable,' as organizations of commonplace everyday activities" (Garfinkel, 1967, vii).

Analysis of Logs

The excerpt we are going to look at comes from an AOL Instant Messenger (AIM) log of PoW-wow 10, conducted in the first year of the VMT Project. Prior to the session, the three participants—Mario, Alice and Fatima (*names anonymized*)— had an opportunity to look at the problem beforehand, but it is not known if any of them had actually solved the problem individually prior to the collaborative problem-solving session. The participants, who described themselves as middle-school students, knew nothing about each other. They were instructed that the moderator's role is restricted to helping them to use AIM and to post any drawings or images the participants may produce (line 011 in Log 9-1). Figure 9-1 shows the problem as it was displayed.
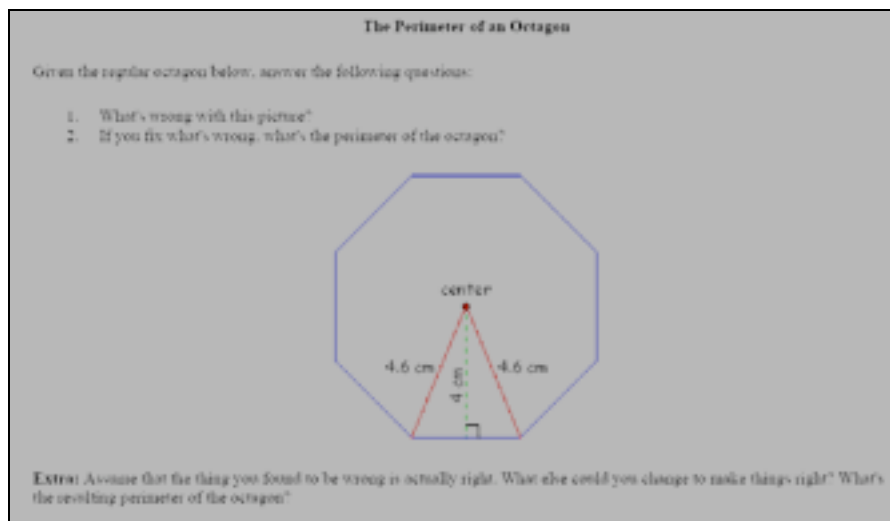

Figure 9-1. The perimeter-of-an-octagon problem.

The interaction recorded in Log 9-1 is preceded by about a minute of introductions. For the next four minutes, the participants negotiate the allocation of participation, the resources that they will use and how to approach the problem using the resources that they have. By line 027, the participants agree on who the participants are and the resources available to them, namely the problem statement

and its accompanying picture, but they are not agreed on the approach to the problem.

Log 9-1.

010	Alice (7:01:05 PM):	Is this everyone?
011	MFPowwow (7:01:15 PM):	If you create a picture that you would like to share with your group, you can mail it to powwow or you can make a direct connection with me.
012	MFPowwow (7:01:24 PM):	This is everyone tonight.
013	Alice (7:01:36 PM):	ok
014	Alice (7:02:04 PM):	so.....
015	MFPowwow (7:02:12 PM):	So you"ve all seen the problem. If you"ve got any ideas, now"s the time to start. :-)
014	Alice (7:02:29 PM):	Ok
017	Alice (7:02:38 PM):	Anyone have a pic?
018	Mario (7:02:58 PM):	Just the one with the problem statement
019	Alice (7:03:17 PM):	lol
020	Mario (7:03:25 PM):	Should we label some points?
021	Mario (7:03:56 PM):	Like, center is O
022	Alice (7:04:04 PM):	We could do that
023	Mario (7:04:21 PM):	Vertex where red line meets is, what, V?
024	Alice (7:04:38 PM):	The center?
025	Mario (7:04:47 PM):	No, down at the vertex
026	Alice (7:04:52 PM):	oh
027	Alice (7:05:00 PM):	That might help

The issue of who the participants are, is raised by Alice in line 010, responded to by the moderator, MFPowwow, in line 012 and acknowledged as settled in line 013. The issue of participants is important because posts whose intended recipients are unnamed or not clearly specified in some form or other, are directed to all the participants. Knowing who are the intended recipients of a post makes it possible to determine who among the participants is allocated participation. A post such as line 017, where Alice is asking whether a desired resource—a picture (stated as "**pic**")—is available, is directed to all the participants, and any of the participants can be expected to produce a response. Mario comes forward, establishing the availability of the desired resource by stating where it is found, namely, in the problem statement.

The visibility of the indicated resource makes it possible for the participants to now make proposals regarding how the problem solving can be approached. Mario proposes labeling some points at lines 020 and 023, providing examples of how labeling can be done. The questions of lines 020, 023 and 024 perform several functions: they attempt to coordinate where the participants ought to be orienting themselves in the problem-solving process by pointing to words in the problem formulation. They also introduce labels as new resources, which can be used for a common approach to the problem. For example, both Mario and Alice use the term "center" which can be found in the diagram (Figure 9-2) and confirm their use of the same resource.
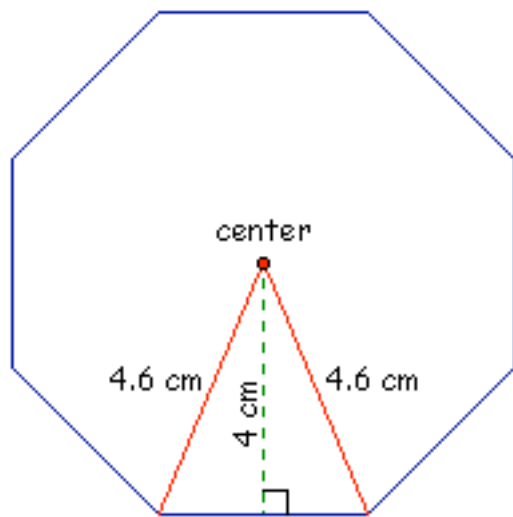
Figure 9-2. The diagram prior to "labeling" by participants.

The questions also propose candidate answers that display what the appropriate answers to the question should be. Supplying a candidate answer enables the person raising the question to show what an acceptable answer can be (Pomerantz, 1988). In this case, supplying candidate answers enables Mario to make Alice participate in labeling. It also enables Alice to get Mario to participate in the approach she starts when she asks, "**Anyone have a pic?**" in line 017. Through the use of candidate answers, participants are able to agree that the diagram is a resource that will be used in the problem solving.

The type of participation in the problem solving is also negotiated. In the process of agreeing that the diagram is a common resource, there is negotiation regarding how the diagram is to be used in the problem solving. The negotiation of participation includes agreeing in what order several approaches may be used. Thus in line 028 (Log 9-2), Alice proposes finding out what is wrong with the picture first. This proposal, if taken up, would expect Mario to stop labeling. However, Mario, instead of stopping, asks Alice to label a point.

Log 9-2.

028	Alice (7:05:16 PM):	Lets find out whats wrong with the pic first.
029	Mario (7:05:20 PM):	You name where the green line meets the base
030	Alice (7:05:30 PM):	B
031	Alice (7:06:19 PM):	I have an idea that might help us find whats wrong with the pic.
032	Mario (7:06:30 PM):	We could use good ol' Pythag thm to see what BV is
033	Alice (7:06:40 PM):	Lets not

After participating in the labeling, Alice repeats her presentation of an alternative to labeling. The tack that Alice takes in line 031 is different from that made in line 028. By posting that she has an idea, she is proclaiming that she has an idea that she would like to be asked about. Being asked for her idea would constitute an uptake of her proposal. She is thus continuing her attempt to convince the other participants to

use her approach first, as she proposes in line 028. But this is again not taken up as Mario proposes to use the Pythagorean Theorem together with the labels B and V to find what BV is. Alice then unequivocally opposes Mario's approach and the ensuing proposal to use the Pythagorean Theorem, by posting "**Lets not**" at line 033.

By line 033, it is established that the participants are using a common resource, a labeled diagram (Figure 9-3). While it is Alice who first brings up the possibility of using a picture as a resource by asking, "**Anyone have a pic?**" in line 017, it is Mario who initiates its labeling. By line 30 three points are labeled and all the labeling is considered complete. Subsequent postings use these labels; the chat participants use them in combinations to frame their discussions. For example, Mario proposes that the Pythagorean Theorem can be used to compute the length of BV. Through the labels, participants are able to specify which parts—initially with predefined values and later including the participant-supplied labels—of the diagram, are being referred to. Furthermore, by describing the Pythagorean theorem as "**good ol'**," Mario calls the attention of the participants to a consideration that the Pythagorean Theorem is an established method that they are familiar with. It is reasonable to claim that if the participants were labeling their own copies of the diagram, they would have had, at the end of line 30, a diagram labeled like Figure 9-3.
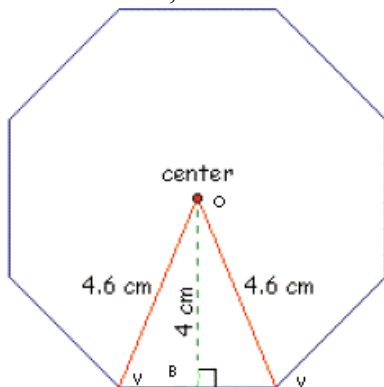

Figure 9-3. The labeled diagram.

The labeling and use of the diagram is thus an interactional achievement. While the initiative for labeling is pushed forward by Mario, the participation of the other participants is critical for its acceptance, even though that acceptance may be a grudging one. This acceptance is displayed in their subsequent use of the labels.

The attainment of agreement regarding what are acceptable to the group as common resources does not mean an end to negotiation. The same resources may be used later to produce a new proposal to oppose what is being presented as a consequence of the agreement on shared resources. The outright rejection of Mario's suggestion to use the Pythagorean theorem is such an example; its position characterizes it as Alice's defensive stance. But Mario addresses the objection and continues his approach. It is noteworthy that Alice's rejection of Mario's proposal (see Log 9-3) is not based on what has been agreed about in previous postings; she bases her argument on the problem statement, "**It states that something is wrong with the pic.**"

034	Mario (7:06:46 PM):	What's your idea?
035	Alice (7:07:01 PM):	It states that something is wrong with the pic.
036	Alice (7:07:08 PM):	so we can't find what BV is
037	Mario (7:07:31 PM):	Yeah, and I think if we 'found' BV, it would be something not possible

The rejectionist stance of Alice in line 033 opens up a possible range of responses. The stance can be ignored, it can also be rejected outright or it may be taken up. The latter may lead to a reorientation of the group to Alice's approach in place of wherever the group may be. When Mario posts "**What's your idea?**" in 034, it signals an uptake: asking Alice to state her position and suggesting a new orientation toward Alice's proposal. Mario's posting at line 034 comes across as a response to Alice's line 031. Mario wants to know the resource—the idea—being held back in line 031. Furthermore, it shows Mario interrupting his own presentation to seemingly favor an uptake of Alice's idea. Alice takes the turn and uses, in line 036, the same label, "**BV**," used by Mario in line 032.

Alice now repeats, in line 035, earlier claims made at lines 028 and 031 by citing the wording of the problem. By referring to its wording, she positions herself as adopting the perspective of the problem designer and claiming what the problem designer would accept as a valid approach for solving the problem. She now states that what Mario proposes to find cannot be found based on what was said in the problem. The word "**so**" connects her present claim about the futility of finding BV to the authority of what was stated in the formulation of the problem. Lines 035 and 036 thus come across as extreme case formulations, where not finding BV has to do with the problem statement that something is "**wrong with this picture**" (Figure 9-1) and where not finding BV is proposed as a phenomenon "in the object or objective rather than a product of the interaction or the circumstances" (Pomerantz, 1986). Furthermore, Alice uses the inclusive word "**we**," softening a dispreferred criticism of what Mario is trying to do. The linking of the claim about BV to the wording of the problem also makes it possible for her to disagree with Mario without directly claiming that the latter is mistaken in proposing to look for BV.

The two different ways through which Alice and Mario approach the problem solving are now visible. While Mario uses labeling and builds up an argument to use the Pythagorean theorem, Alice uses the wording of the problem to argue the opposite. However, they both use the labels in orienting the participants in the problem-solving session and in their negotiating activity. An example of this takes place when Mario, in line 037, agrees with the claim of Alice by modifying his claim about BV. In response to Alice's posting that "**we can't find what BV is**," Mario posts "**Yeah, and I think if we 'found' BV, it would be something not possible**." While his use of "I" qualifies his subsequent claim as an opinion, the claim opens up another way to approach the problem, which is to show that a computation of BV would result in a finding that is incompatible with known parts of the problem. Mario's post thus makes it possible for the participants not to have to choose among the competing approaches exclusively.

Alice's claim is accepted but Mario continues using his approach (see Log 9-4). He computes for BV and then makes a claim about the picture using the term "**central angle**" in line 046.

Log 9-4.

038	Mario (7:08:10 PM):	16 + BV^2 = 21.16
039	Mario (7:08:20 PM):	BV^2 = 5.16
040	Alice (7:08:23 PM):	I got it
041	Alice (7:08:29 PM):	I know whats wrong with the pic
042	Mario (7:08:31 PM):	BV = 2.27
043	Fatima (7:08:44 PM):	ok. now i'm following!
044	Mario (7:08:47 PM):	That makes the base about the same as the radius
045	Mario (7:09:01 PM):	That can't be
		Alice has left the chat room. (This is a system message.)
046	Mario (7:09:19 PM):	Central angle would be about 60 deg, that way
047	Fatima (7:09:30 PM):	yes
048	Fatima (7:09:35 PM):	i see
		Alice has entered the chat room. (This is a system message.)
049	Alice (7:10:05 PM):	Sorry
050	Alice (7:10:10 PM):	Lost connection
051	Fatima (7:10:13 PM):	what happened?
052	Fatima (7:10:15 PM):	oh
053	Fatima (7:10:26 PM):	why does that happen so often?
054	Fatima (7:10:31 PM):	nvm
055	Mario (7:10:43 PM):	Do you have what's done so far
056	Alice (7:10:51 PM):	What did you say BV was?
057	Fatima (7:11:05 PM):	2.27
058	Mario (7:11:10 PM):	With the numbers given, BV would be
059	Mario (7:11:11 PM):	yeah
060	Alice (7:11:14 PM):	I think thats wrong
061	Fatima (7:11:19 PM):	how so?
062	Alice (7:11:28 PM):	I know whats wrong with the pic
063	Mario (7:11:31 PM):	base would be twice that
064	Fatima (7:11:33 PM):	what
065	Mario (7:11:41 PM):	4.54 ish
066	Alice (7:11:45 PM):	The diagnol is not 4.6
067	Mario (7:11:51 PM):	Right
068	Fatima (7:12:02 PM):	exactly
069	Mario (7:12:14 PM):	Otherwise, the red lines and the base are almost an equilateral triangle
070	Alice (7:12:32 PM):	I think this requires trig
071	Mario (7:12:50 PM):	So, one possible wrong thing is, this is really a hexagon
072	Alice (7:12:56 PM):	No
073	Mario (7:13:01 PM):	Right
074	Alice (7:13:09 PM):	Im talking about the triangle diagnol
075	Mario (7:13:11 PM):	Let'sd stick with octagon
076	Mario (7:13:24 PM):	So we assume 4 is right
077	Alice (7:13:32 PM):	yes

Mario continues his approach and at line 071 points out a possible wrong thing, that the octagon (Figure 9-5) is really a hexagon (Figure 9-4). If the base and the radii are the same length, then the internal triangles are equilateral. Equilateral

triangles have three internal angles of 60°. A regular polygon with internal angles of 60° would be six-sided (hexagonal), because the 360° around the center would be divided 360°/6=60°. The internal angles of an octagon are 360°/8=45°, forming triangles whose base is smaller that the two other sides. In showing the consequence of the computation of BV, Mario demonstrates that the value of BV results in a hexagon instead of an octagon and displays a finding that is incompatible with what is stated about the problem.
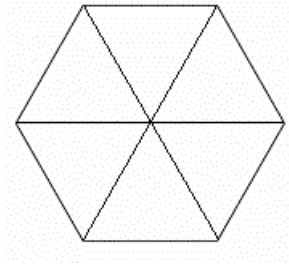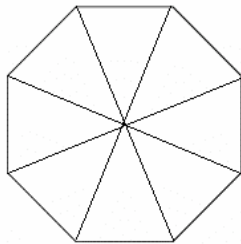

Figure 9-4. Hexagon.

Figure 9-5. Octagon.

Between Mario's postings building up to the claim that the octagon may really be a hexagon, Alice repeats her claims about knowing what is wrong with the picture (lines 060 and 062) and offers the claim that the diagonal is not 4.6 (lines 066). Mario's reasoning is based on the labeled dimensions of the diagram while Alice's reasoning is based on the problem statement that there is something wrong with the picture. By implication, its listed dimensions may not be correct, thus supporting her later claim that the diagonal is not 4.6. This seeming conflict between the competing approaches to the formulation is resolved when Mario accepts her claim by posting "**Right**" at line 067 and continuing his presentation by posting line 069 which incorporates her "**diagonal is not 4.6**" and his result "**4.54 ish**" in the post "**Otherwise, the red lines and the base are almost an equilateral triangle**." The acceptance of line 069 is designed to lead to the acceptance of line 071. After Alice posts "**No**" at line 072; Mario withdraws his suggestion about the inaccuracy of the shape of the figure through lines 073 and 075, where he explicitly announces an invitation to all the participants to "**stick with octagon**" that is, assume that the figure has the correct shape. This is then followed by line 076 where he asks the participants to assume that "**4 is right**." Alice's claim that "**the diagonal is not 4.6**," is thus accepted, as that claim cannot be simultaneously true if 4 is assumed to be right.

Line 074 is an explanation attached to the "**No**" in line 72 and is an elaboration of Alice's line 070 posting about a possible use of trigonometry for the diagonal. However, It is instructive that Mario does not use Alice's self-repair in 074. Had he taken it up, another approach could have been started. But by taking up only the first part (line 072) of a two-part post (lines 072 and 074), as he does here, he is able to include the part of Alice's assertion, which can be taken as a rejection of line 071, and state an invitation to produce an approach worded in a form acceptable to her. Mario's new proposal "**to stick with octagon**" and "**assume 4 is right**" at lines 75 and 76 meets with Alice's "**yes**" at line 077, a token of agreement. The rest of the log after line 077 then shows the participants using the same approach to solve the other parts of the problem, confirming their agreement regarding both approach and participation in solving the rest of the problem after this contentious phase.

Forms of Negotiation in Chat

Negotiation in the Choice of Approach

Lines 020 to 030 reveal Mario and Alice trying to get the ensemble to work on the problem, with each wanting the ensemble to use their approach. Mario tries to involve the other participants in labeling the diagram (lines 020, 021, 023 and 029) to set up an approach to solving the problem at hand while Alice wants them to "**find out what's wrong with the pic first**" (line 028). By line 32, there are two proposals: Alice's yet-to-be-articulated idea (line 031) and Mario's "**good ol' Pythag thm**" (line 032). While there is no visible attempt by either Mario or Alice to make their approaches work together, both are keeping track of each other's approaches. This mutual tracking is made visible in line 036 when Alice claims, "**so we can't find what BV is**" and in line 037 when Mario agrees with Alice when he posts "**Yeah, and I think if we 'found' BV, it would be something not possible.**" While both Mario and Alice appear resolved to use only their own approach as the exclusive approach which should be used by the whole group, and act accordingly, they come up with the same conclusion by using the resources that they marshal separately, present separately, but finally use cumulatively. This cumulative use is made possible by their mutual attention to each other's separate but simultaneous presentation of their own approaches. The timing of these postings also plays a part in these mutual uptakes.

Negotiation in the Choice of Sequence of Approaches

Group members may have their individual approaches to the problem. These individual approaches surface in the interaction if group members consider them relevant to the task. There is visible contention for which approach can be used first. Mario reveals his approach first, but later, participants are made aware of another possible approach when, in line 028, Alice posts "**Lets find out whats wrong with the pic first**"—proposing that another task be done prior to the labeling being done at the present. The unequivocal opposition of Alice (made visible in line 033's "**Lets not**") to

Mario occurs after the latter proposes a claim made on the basis of the labels made prior to line 032. Alice proposes the exact opposite of the claim in line 036. There is a shift however here, because the direct claim that the group "**find out whats wrong with the pic first**" which would make Mario approach come later, is changed to a claim about finding what's wrong with the picture, and pointing out that the results from Mario's approach would not work. Thus, by subtly dropping the demand to let the group use her approach first before labeling and using the same labels proposed by Mario, Alice is able to get Mario to stop his presentation to take up her proposal, and state a conclusion consistent with the claim being made by Alice.

While both participants try their approaches without a visible attempt to contribute to each other's approaches, both Mario and Alice remain attentive to each other's postings. For instance, we see Mario stopping to ask Alice in line 034, and in the process creating an opening for the latter to present a proposal. Alice then points to a drawing, a resource preexistent to the resource created by Mario. This technique to appeal to a preexisting resource is repeated in another section of this excerpt, in line 066, when Alice claims that "**The diagnol is not 4.6**." This posting refers to either of two red lines in the drawing (Figure 9-2). The value 4.6 associated with the red lines is associated to the "**diagnol**" in line 066 and is made to contradict Mario's claim that it is "**.54 ish**." However, similar to what happened in line 037, Mario accepts the claim and puts the claim within his own explanation. By making pauses in his own presentation, Mario is able to proceed with his approach by incorporating Alice's claims. Both proponents raise the priority of their respective approaches by invoking justifications that claim more than they initially try to prove, typically by including claims made by competing approaches. While neither Mario nor Alice is able to establish a clear priority that either of their approaches can be completely tried out first, by taking sections of each other's approaches, they come up with postings where they agree. They agree that BV cannot have a value which is consistent with known labels of the problem's diagram and that they can assume that the label "4" is right.

Negotiation in the Contribution to Unfolding a Particular Approach

While approach proponents do not seem to try to reconcile their approaches, there are attempts to elicit support from other participants. This support is solicited without a presentation of an overall goal to which the components of an approach contribute. Mario's invitation to label some points is not preceded by an explanation of how the labeling can contribute to the problem-solving; Alice's approach, which starts with a claim that there is something wrong with the picture, does not offer a workable strategy for finding out what indeed is wrong with the picture, but she does invite the others to ask her about her idea by claiming that she has an idea.

It may well be that labeling may be a way of orienting the participants. The plan to use the Pythagorean theorem is clear only after the labels have been put in. This overall goal is only gradually revealed in the unfolding of the interaction. It may well be the case that both Mario and Alice are merely exploring the problem space and do not have an explicit overall proposal that they can present to the whole ensemble. For

their individual explorations to go farther, each tries to "recruit" participants to push the exploration along. This recruitment is seen in Mario's postings, which call on the participants to supply labels to parts of the diagram that Mario is indexing. Similarly, Alice brings up a proposal to find out "**whats wrong with the picture**" and then presents her idea that "**we can't find what BV is**." Mario agrees with Alice's idea and then proceeds to find a value of BV and concludes with line 046, which shows his approach that demonstrates "**Central angle would be about 60 deg, that way**." Mario thus contributes to Alice's method to show that there is something wrong with the picture.

The participants use each other's postings to develop a point of view which changes the direction of the initial posting, contributes to the unfolding of the other's approach and presents another picture for the consideration of the other participants. A new sense of the problem makes its appearance and becomes part of the joint meaning available to the participants.

Changing Modes of Participation and Negotiation

While participants involve other participants in the proposals that each individually puts forward, agreement is not reached by convincing other participants to adopt the proposals they advance. Agreement is achieved by including parts of claims made by others in competing proposals. Agreement is attained not by posting the result of a zero-sum approach that points out that a proposal is completely wrong, but by the appearance of a post which includes components of the other's proposal.

For example, it is instructive that Alice does not, at any point in the interaction, disagree with the computations of Mario, though she takes issue with the consequences of those computations. Neither does Mario take Alice to task for not offering any argument in favor of the claim that something is wrong with the picture. A consequence of Alice's claim is that none of the pre-defined labels can be trusted. Both Mario and Alice initially predict what they think would be the findings from their respective approaches. The "**BV**" which Alice claimed cannot be found in 036 is described by Mario as "**something not possible**" in line 037. When BV is computed, the resulting hexagon confirms Alice's claim that there is something wrong with the picture. Agreement is reached by incorporating the results of the competing approach into a conclusion of a proposal being unfolded. When these incorporations are made, there is no visible objection from the proponent of the competing approach, whose result is appropriated by the other approach. There is no objection from Alice when Mario claims that even if BV were to be found, it would be a value that is not possible. Similarly, there is no objection from Mario when Alice claims that the diagonal is not 4.6, a finding which is consistent with Mario's result that the representation is more like a hexagon than an octagon.

Member Methods for Negotiation

Participants negotiate when there are competing proposals that appear in their problem-solving interaction. As proposals are advanced, they may be accepted, rejected or ignored. Acceptance is shown in an uptake of the resources offered by the

proponent of the proposal. The participants use these resources in similar or compatible ways. Acceptance thus means that the participants build on each other's postings and co-construct their framing of the problem, crafting their solution or assessing the adequacy of their proffered solution.

In the face of rejection, participants may adopt other strategies to change the allocation of participation. The spurned proponent may recycle the proposal or post an alternate message, which claims to have some idea that would shed light on the group activity. However, this alternate message would require the other participants to ask the rejected proponent to reveal the idea. If this ploy works, then a counter-proposal may arise and begin another cycle of exchanges. If a proposal is ignored, its proponent may decide to go along with the other proposal, or present a new proposal, or lurk.

These member methods may not appear different from negotiation in a face-to-face setting, since acceptance, rejection or indifference can be communicated through postings as well as through talk. However, in chat acceptance, rejection or indifference may not appear immediately after the proposals to which they would be paired if the interaction were face-to-face. This makes it possible for participants who would otherwise be in an impasse to select parts of a long series of related postings that they can append to their own postings to break an impasse and thereby produce agreement. Thus we find Mario selectively appropriating the postings of Alice and including them in his own presentation. Similarly, we find Alice using the labels instigated by Mario in making her own contrary claims regarding the reliability of labels. After these appropriations, the interaction continues to another issue.

Participants recognize agreement when they post tokens of agreement in reaction to other participant's postings. Prior to these tokens of agreement, participants show that they are aware that there is some problem, that a solution has to be found, that the solution has to be implemented. The awareness of a problem is expressed in postings that supply additional resources to help frame the problem. For Mario, these additional resources are in the form of labels that eventually frame the problem as a type that can be solved using the Pythagorean theorem. For Alice, labeling is not as consequential since there is something wrong with the picture and by implication, the predefined labels are suspect. Mario proposes a solution which is based on the application of the Pythagorean theorem while Alice proposes a solution which ultimately assumes that one of the labels is not correct, and she chooses that the diagonal is not 4.6. Mario, in proposing the Pythagorean theorem, puts forward an approach that the participants are assumed to be familiar with, while Alice proposes her approach based on the problem-designer's formulation that there is something wrong with the picture.

We also note that the participants try to negotiate the order in which varying approaches may be applied to the problem at hand. Both Mario and Alice try to get the other participants to apply their approaches first. Both of them do not criticize each other's approaches and work independently of each other until such a time when either uses some resource produced by the other to advance her own approach. Thus, Alice uses the labeling "BV" that Mario first used to point out how the latter

cannot produce a correct result from the latter's approach. Mario, in return, uses this claim to proceed to a computation of BV, which then produces a result, which is not directly traceable to the use of the Pythagorean theorem but rather to a set of properties associated with equilateral triangles, octagons and hexagons.

Taking these two aspects of interaction—the negotiation to agree on the approach and the negotiation to agree on the order in which the different approaches are applied—we find that the independent proposals of individual participants all fail. In spite of this, the participants agree that finding BV is either impossible or that its value would be "*something not possible.*" The group participants have reached a common understanding of why this is the case. That is, they have solved the given mathematical task as a group. The group problem-solving session is then able to continue on the basis of the points thus agreed on.

If one conceives of the problem solving as the effort of individuals, then one would predict a strong likelihood that the session reviewed in this chapter would break down. Two strong willed students brought incompatible approaches to the given task, and each vigorously resisted the approach of the other. However, through the processes of negotiation analyzed here, the differences were resolved in a productive way that led to a solution of the problem and a continuation of the interaction. The resolution of difference did not take place through a vote among preexisting personal opinions, compromise, bargaining or consensus, but through a subtle and selective building of each participant's proposals upon the up-take of the other participant's proposals. A shared framing of the problem—or a joint problem space—was co-constructed through the inter-animation of alternative perspectives on the problem. Through fine-grained analysis of the chat log, it was possible to characterize various interactional methods that were employed by the group to achieve a productive inter-animation.

The excerpt that was analyzed can be seen to have been driven forward by the interactive moves between participants, motivated by their different perspectives. From a methodological viewpoint, it is important to note that the driving force is not the individuals as agents, but the tension between them. The math solution does not arise directly from the mental representations of the individual students, but from the group effort to respond to the conflicting differences and from the interplay between the participants. Of course, the brains of each student were necessary to interpret the group meanings created in the interaction and to articulate the utterances that were posted in the chat in response to the on-going discourse, but the problem framing, the joint problem space, the solution path, the meaning making all took place at the group level in the visible, persistent chat.

What can be said about learning in this case study? If we talk about the group learning—having followed a path to that solution and having arrived at an understanding of the solution of the problem—then we can say that the group learning was driven by the process of interactively resolving the differences of proposed approaches. If, further, we assume that the individual students learned something from the experience, we can say they did so by "individuating" the group lesson, making it their own and integrating it into their personal understanding, where it can serve as a set of resources for future mathematical discourses (including

internal discourses of thought). Because the effort to resolve differences in the chat discourse kept both Alice and Mario focused on the proposals of the other, it is likely that they will each internalize something of their opponent's perspective. In this sense, their individual learning will be driven by the confrontation with a perspective that conflicted with their own. Experiences like these lead to our ability to learn on our own by reading and even by thinking about perspectives that conflict with our own initial ideas. Thus, analysis of this case study seems to provide insight into grand theories of individual and collaborative learning through cognitive conflict and inter-animation of perspectives as driven by the resolution of differences.

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