Negotiation's Twists and Turns in a Synchronous Online Collaborative Mathematics Problem-Solving Session

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Abstract: While negotiation has been studied under domains such as communications, learning sciences and their associated theories of learning, it is rarely studied as an interactional phenomenon constituted by its participants engaged in a synchronous collaborative problem-solving session in a text-only computer-mediated environment. A fine-grained analysis using a method inspired by conversation analysis describes negotiation as it is undertaken by a small group engaged in a synchronous collaborative problem-solving activity in the said environment. Describing negotiation through this analysis means seeing how participants produce agreement through the tools available to them. 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 also negotiate which approach is in use, who are 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.

INTRODUCTION

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 to perform 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 be negotiation. Negotiation, defined as 'a discussion intended to produce agreement' or 'the activity or business of negotiating an agreement'[1] is indisputably a key activity in 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 researches 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 also studied both under theories of learning and 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 (Stahl, 2006a, 182; Vygotsky, 1930/1978, 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 a common ground for understanding' (Stahl, 2006a, 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 people's ideas back together, thus making sustained, in-depth knowledge building possible (Stahl, 2006a, 182).

Negotiation is also studied for its role in the dynamics of small problem-solving groups. 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 representation (Beers, Boshuizen, & Kirschner, 2003). Two parts in negotiation are described, a process of negotiation of meaning and a process of negotiation of position as well as a list of primitives specified: contribution, clarification, verification, acceptance/rejection and position (Beers et al., 2003).

The mutual impact of computer support and negotiation

The field of CSCL is especially interested in negotiation in collaborative learning (Stahl, Koschmann, & Suthers, 2006). 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 which follow the rubrics of *flexible structuring* are intended to structure interactions. *Flexible structuring* operationalizes its design approach by 1) providing a restricted set of communicative acts that can be used in the interaction, without necessarily enforcing their use in given contexts, and 2) 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 and 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' (1992, 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 which leads to negotiation towards 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, Pirkul, Varghese, & Barhki, 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 study involving middle-school students using a rocket simulation shows such results (Stahl, 2004). In a study of a chat environment with referencing capability for both its graphics whiteboard and its chat space, great variability is observed in how the referencing mechanisms are used in knowledge negotiation (Cakir, Sarmiento, & Stahl, 2006).

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. 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 means a fine-grained analysis of the postings produced by the participants in the course of their online synchronous problem-solving session is essential. The paucity of research which documents how negotiation is achieved in an online synchronous collaborative problem-solving session is a motivation for this exploratory study to describe negotiation as it is experienced and recognized by a collaborative problem-solving group.

In this paper, 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 is this excerpt will indicate how important negotiation is to the accomplishment of collaborative effort and will note the peculiarities of such negotiation in a CSCL context.

DATA AND METHODOLOGY

The data we present in this analysis comes from a log of a problem-solving session conducted by the Virtual Math Teams Project. This project is an NSF-funded research program that investigates the innovative use of online collaborative environments to support effective K-12 mathematics learning.[2] The chat environment used by the participants is AIM®. The unconstrained setup of the chat environment means that the participants will not be restricted in both the format and the content of their postings.

We intend to 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 the participants themselves. We use a method of analysis developed from conversation analysis. 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 (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). We believe that a fine-grained analysis of negotiation such as this can further the design effort for better interfaces and affordances that would support negotiation in synchronous online computer-supported collaboration.

ANALYSIS

This excerpt comes from an AIM® log of PoWwow 10. 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 had described themselves as middle-school students, knew nothing about each other. They were also instructed that the moderator's role is restricted to helping how to use AIM® and help post whatever drawings or images the participants may produce (line 011). Figure 1 shows the problem as it was displayed.

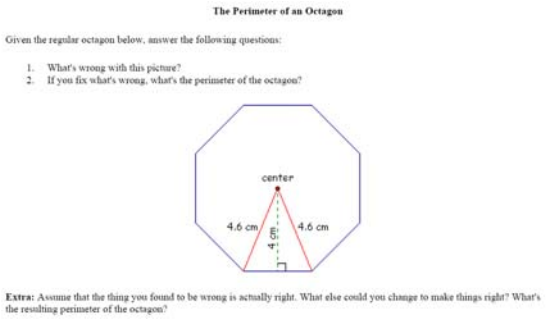

Figure 1. The Perimeter of an Octagon Problem

This excerpt 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 are not agreed on the approach to the problem.

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 MFPowwow in line 012 and acknowledged as settled by 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 or are 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, putting 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 2) and confirm their use of the same resource.

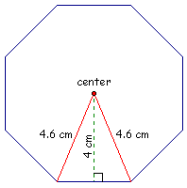

Figure 2. The diagram prior to 'labeling' by participants

The questions also propose candidate answers which 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 in participation includes agreeing in what order several approaches may be used. Thus in line 028, 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.

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 makes 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 has 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' 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 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'* (good old)', 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 3.

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. Its use as a shared resource for framing an approach to the problem is an interactional achievement since the use of labels requires their acceptance by the group that the labels as resources for group interaction for problem solving. This acceptance is displayed in their use of the labels.

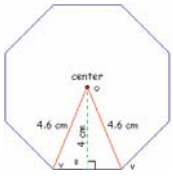

Figure 3. The labeled diagram

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

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

Furthermore, 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 inviting to 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 representing 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 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, p. 220). 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. They both use labels 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 which is incompatible with known parts of the problem. Mario's post thus makes it possible for the participants not to have to choose one among the competing approaches exclusively. Alice's claim is accepted but Mario continues using his approach. He computes for BV and then makes a claim about the picture using the term 'central angle' in line 046.

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

Mario continues his approach and at line 071 points out a possible wrong thing, that the octagon (Figure 5) is really a hexagon (Figure 4). In showing the consequence of the computation of BV, Alice demonstrates that the value of BV results in a hexagon instead of an octagon and displays a finding which is incompatible with what is known about the problem.

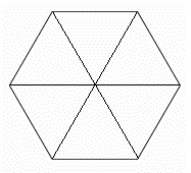

Figure 4. Hexagon. All the internal angles of the 6 triangles are 60, so all the sides of the triangles would be the same.

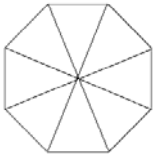

Figure 5. Octagon. The eight angles at the center of an equilateral octagon are 45 = 360/8.

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.

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

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.

FINDINGS

We note that negotiation appears in the allocation of participation in the choice of approaches to the problem, the sequence in which different approaches are used and contribution to the execution of an approach. Negotiation in the choice of approaches to the problem is constituted in the participation which tries to reach agreement regarding which of different approaches actually gets used in problem solving. Negotiation in the sequence in which different approaches are used is constituted in the participation which tries to reach agreement regarding the order in which different approaches are used. This negotiation is visible in the achievement or failure to decide which approach is used first, which gets tried next, then third and so on and so forth. Negotiation regarding contribution to the execution of an approach is constituted in how participants contribute to the unfolding of a particular approach.

In the online environment of AIM® where indexical references are limited to chat postings, all negotiation is conducted through them. The posting of proposals, as well as concurrence in, disagreement with, or indifference to them are also through chat postings. The way proposals are unfolded and the sequence in which they are developed are a matter of participation decided not only by their respective proponents but also by all the participants who concur in, disagree with or ignore the proposals concerned. Moreover, unlike in a face-to-face conversation where overlaps between utterances, occasioned by participants talking at the same time, are both dispreferred and infrequent, postings in a chat environment appear in a sequence which show no indication of when their poster started to produce them. The sequential appearance of the postings do not show the possible overlaps during which participants may have been typing simultaneously for the appearance of each posting only shows the sequence in which participants posted their productions. Consecutive postings may not necessarily be adjacency pairs where a post responds to the nearest previous post, leading to the well documented phenomenon of chat confusion (Fuks, Pimentel, & Pereira de Lucena, 2006; Pimentel, Fuks, & Pereira de Lucena, 2003). Even though there are disruptions in the turn-taking sequence, participants conduct their problem-solving activity through the features of the chat environment and use whatever resources usable for negotiation, are accessible through the medium.

Undeniably, there are other resources such as web sites which participants can bring to a computer-mediated interaction which are not available in a face-to-face interaction but these resources in an online synchronous collaborative mathematics problem-solving are made relevant only to the extent that they are made visible in the interaction which is recognized by its participants as negotiation. What is visible in the interaction is what is made visible in or reported through the AIM® chat window. Thus, the interaction which participants recognize as producing agreement, that which is termed negotiation, is what can be recognized as negotiation by the participants themselves in and through the chat window.

Negotiation in the choice of approach

Lines 020 – 030 reveal Mario and Alice trying to get the ensemble to work on the problem with each wanting the ensemble to use his 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 for 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 approaches as the exclusive approach which should be used by the whole group, and act accordingly, they come up with 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 play a part in these mutual uptakes (Stahl, 2006b).

Turning then to a description of negotiation as the production of agreement in this excerpt, the negotiation to choose an approach fails since the participants fail to agree on how the problem should be approached. In the case of Mario, the effort to negotiate is conducted by giving Alice an opportunity to participate in the unfolding of the approach he is advancing. We find Alice getting involved in the production of the labels while Mario begins to incorporate the claims of Alice into his approach. Alice on the other hand, negotiates by repetition, expressed through lines 028, 031 and 035. As would be eventually revealed, Mario’s approach consists in showing that the

dimensions given in the diagram are not all correct. Alice's approach consists too, in proving that the 'diagnol (diagonal)' is not 4.6, which is another way of stating that not all the given dimensions are correct.

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 pic 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. Thus 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'. Undeniably, this posting refers to either of two red lines in the drawing (Figure 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 which claim more than they initially try to prove, typically by including claims made by competing approaches. While neither Maria 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. Mcblz'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 doable 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 which 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 which 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 shows '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.

Different approaches and changing modes of participation

Participants in a collaborative problem-solving session bring to it their different perspectives and approaches. As these different approaches are unfolded, changes occur in the modes of participation in the session. The unfolding of an approach requires changes in the strategy for drawing participation. These changes in the strategy for drawing participation result in different modes of participation by and interaction among the participants. A change in strategy for interaction changes the organization of participation.

When labeling is initiated as a group task, the projected and desired participation from the other participants consists in assigning labels to locations in the diagram. The different ways by which the labels are produced indicate changes in the strategy for drawing participation in Mario's labeling approach. At the beginning of the excerpt, participation is proposed and actualized by Mario as labeling. A few postings later, Alice joins in even as she does not show much enthusiasm for it. Thus, the labeling in 023 is quite different from that of 021. In the former, when Mario marks the center as 'O', he establishes himself as a participant who makes suggestions for a problem-solving approach. In the latter, Mario presents 'V' as a possible label for 'Vertex where red line meets' but where the expected response is for Alice to ratify that 'V' is to used to label 'Vertex where red line meets'. This is in marked contrast to the labeling at 029, where the turn is given explicitly to another participant, and taken by Alice, to label 'where the green line meets the base' as 'B'. Just as the action of labeling is constitutive of the framing of the problem, it also is constitutive of the allocation of participation. We note that at 020 Mario takes the initiative in proposing doable steps to solve the problem. As more labels are put in, there is a change in Alice's participation. By line 028 Alice is suggesting a different approach and by line 031 is claiming to have an idea which would enable the group to find out 'whats wrong with the pic.', a idea revealed by Alice only after Mario interrupts his presentation of his approach.

The use of labels defines the stances and thus, the participation of the participants. It is only after line 032 when Mario proposes the 'good ol' Pythag thm' (Pythagorean Theorem) that Alice directly opposes the proposal by stating that 'we can't find what BV is'. In using the label BV, Alice uses the same resources Mario had arranged for the exposition of his proposal, but uses them to press Mario not to continue his approach. After line 036, though Mario apparently continues using the Pythagorean Theorem, the result he produces finally converges on the same claim as Alice's. By line 071, Mario is posting 'So, one possible wrong thing is, this is really a hexagon'; though the diagram for the problem is that of an octagon. Equivalently, Mario is claiming that while the representation is that of an octagon, the given dimensions are more consistent with the dimensions of a hexagon. There is a claim that something is identifiably wrong with the picture; Mario reasons out that BV is an 'impossible' value, while Alice takes issue with the dimension of the diagonal, given as '4.6'. It appears here that the stance of Mario is based on accepting the initial values of the labels and showing that the labels become incompatible with each other while the stance of Alice is based on a non-acceptance of the labels at face value because the problem statement itself says that something is wrong with the picture. The difference in their use of labels thus causes both participants to seemingly proceed independently while watching each other's productions closely. Proceeding independently in a synchronous online environment does not carry the same penalty compared to analogous face-to-face interactions where face issues inhibit the former (Goffman, 1967). Online participants can neither shout each other down nor effectively keep each other from posting; the worst they can do is ignore each other's postings. It is a common desire to solve a problem which can keep them paying attention to each other's postings though they may not accept each other's explanations.

Changing modes of participation and negotiation

While participants involve other participants in the proposals that each individually forwards, 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 which 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 result a 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 which 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 instead of an octagon.

Member Methods for Negotiation

We note that participants negotiate when there are competing proposals which show up in the interaction of problem solving. 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 accepted proposal. The use of the resources thus taken up appears in the interaction as resources used in similar or compatible ways by the participants who have accepted the proposal. 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 which 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.

While these member methods may not appear different from negotiation in a face-to-face setting, since acceptance, rejection or indifference are communicated through postings, whose production cannot be monitored but read only in their final form, 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 which they can append to their own postings to break an impasse and thus produce agreement. Thus we find Mario 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. We note that after these appropriations, the interaction continues to another issue.

We thus note that participants recognize agreement when they post tokens of agreement in reaction to other participant's postings whose previous parts are made to fit a competing approach. 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, and that there are misalignments according to how any one of the three is assessed, understood or taken into account by other participants in the interaction.

The awareness of some problem is expressed in postings which supply additional resources to help frame the problem. For Mario, these additional resources are in the form of labels which eventually frame the problem as a type which 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' which 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 (and consequently, equiangular) triangles.

Taking then these two situations of interaction namely, 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 both negotiations fail because no agreement is reached on either a common approach or the order in which they can be tried. In spite of these, the participants agree that finding BV is either impossible or even if it were found, its value would be 'something not possible'. There is agreement on a result which can be found using either proposal though neither

proposal is wholly used by the whole group. The interaction is then able to continue on the basis of the point thus agreed on.

We find then that participants in this interaction simply append each other's findings to each other's approaches to come to an agreement. The agreement is confirmed by the absence of any complaint against this mutual incorporation and appropriation of each other's findings.

NEXT STEPS

This exploratory study has looked at negotiation in an online synchronous collaborative problem-solving environment whose only feature is a chat window. Other environments such as VMTChat[3] offer not only a chat window but a shared graphical space as well. Just as a fine-grained analysis reveals methods through which online participants negotiate in a text-only synchronous online environment, similar methods may be used to examine negotiation in these environments where both graphics and text may be used.

ENDNOTES

[1] negotiation. (n.d.). WordNet® 2.0. Retrieved November 12, 2006, from the website of Dictionary.com: http://dictionary.reference.com/browse/negotiation

[2] http://mathforum.org/vmt/researchers/orientation.html. Retrieved November 14, 2006.

[3] http://mathforum.org/vmt

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