Questioning and responding in online small groups engaged in collaborative math problem solving

Nan Zhou, Alan Zemel, Gerry Stahl, Drexel University, Philadelphia, USA
Email: Nan.Zhou@drexel.edu, ARZ26, Gerry.Stahl@drexel.edu

Abstract: Question asking is central to the interactions that take place in Computer-Supported Collaborative Learning (CSCL) settings. We investigate questioning and responding practices as interactional processes and explore their roles in online collaborative problem solving. We present our analysis of a 12-minute excerpt of three students doing math problem solving collaboratively in an online chat environment as an effort to discover some underlying social practices involved in questioning and responding. The analysis suggests how questions and responses are produced and understood. It also explicates the variety of roles questions can play in the organization of participation and learning in such a collaborative math problem-solving setting.

Introduction

Asking questions has been considered by many researchers to be central to theories of learning, cognition, and education (e.g. Scardamalia & Bereiter, 1991; Graesser, 1994; Ram, 1991). Some believe that the ability to ask questions is pivotal in processes of reasoning, understanding and learning. Questions are, for instance, a powerful and ubiquitous tool used in instructional interactions. An *IRE* (Initiation-Response-Evaluation) model (Mehan, 1979) has been commonly used in classroom settings, the sequence of which is 1) an instructor asks a question for which he or she already knows the answer, 2) students respond to the question, and 3) the instructor evaluates their response (Fox, 1993; Wells, 1999). Studies of the role of teachers' question asking in classroom settings have considered it a means by which teachers retain control within their students' zones of proximal development (Scardamalia & Bereiter, 1991). Studies of questions in classrooms and one-to-one tutoring settings have suggested certain questions for teachers to ask to guide student thinking and to shift students toward more reflective discourse (e.g. Van Zee & Minstrell, 1997; Graesser, 1994). Previous studies have confirmed the importance of elaborated explanations and shown that constructively applying the help received is beneficial for learners (e.g., Webb et al., 2006). In mathematics education, in particular, reform efforts have called for student-centered communication. The National Council of Teachers of Mathematics (NCTM, 1991, p. 35) lists a number of desired teacher behaviors such as "posing questions and tasks that elicit, engage, and challenge each student's thinking; listening carefully to students' ideas; asking students to clarify and justify their ideas orally and in writing; and monitoring students' participation in discussions and deciding when and how to encourage each student to participate."

Although question asking is believed to lie at the heart of learning, it is well documented that students very infrequently ask questions in the classroom, and that their questions tend to be "lower-level" questions (Webb, Nemer, & Ing, 2006). Educational researchers have frequently advocated educational settings that engage students in active learning and problem solving, which often involves students in formulating their own inquiries and asking effective questions. CSILE (Computer-Supported International Learning Environments) is a prominent example of a learning environment designed to support students' intentional learning by encouraging students to ask questions and then using these questions to guide their knowledge building (Scardamalia and Bereiter, 1994).

Computer-Supported Collaborative Learning (CSCL) is a branch of the learning sciences concerned with studying how people can learn together with the help of computer technology (Stahl, 2006b). It proposes the development of software environments that bring learners together and stresses productive social interaction among students. Students are encouraged to learn by expressing their questions and pursuing lines of inquiry together. Within such environments, students usually tend to be more willing to ask questions in a peer group without the pressure from a classroom setting. During collaborative problem solving, students in a small group have to coordinate their activities and work together to "construct and maintain a joint problem space" (Roschelle, 1996) to collaboratively engage in producing solutions. Such a collaborative process inevitably involves activities such as: posing a question, making a proposal, critiquing, providing assessment, agreeing, disagreeing, etc. Collaborative problem solving in a CSCL environment can thus provides a particularly fertile opportunity to examine question asking. Understanding questions in such settings can have an important value in understanding collaboration and learning in CSCL environments, since collaboration is often organized around the action of question and response.

Surprisingly there has been little empirical analysis of question asking and responding in online small-group interactions, specifically in CSCL settings. We have examined the questions in small groups that are engaged in math problem solving in an online chat environment. We are interested in understanding different kinds of

questions asked in this particular setting by analyzing: (1) How is a question designed and produced by participants so that it's adequacy is made evident to participants? (2) What kind of work does a question do in collaborative problem solving? (3) What roles do questions play in collaborative learning? Question-response is one of the common "adjacency pairs" in ordinary conversations (Sacks, 1992). We hold that questions (and responses) are particular and locally situated social facts, and we are interested in questions as the lived achievement of actors who are engaged in the work of *doing* them. In this paper, we present a detailed analysis of one episode of students' interaction, drawing on aspects of conversation analysis (Sacks, 1992) and ethnomethodology (Garfinkel, 1967), as a preliminary step of understanding questions in an online small group setting.

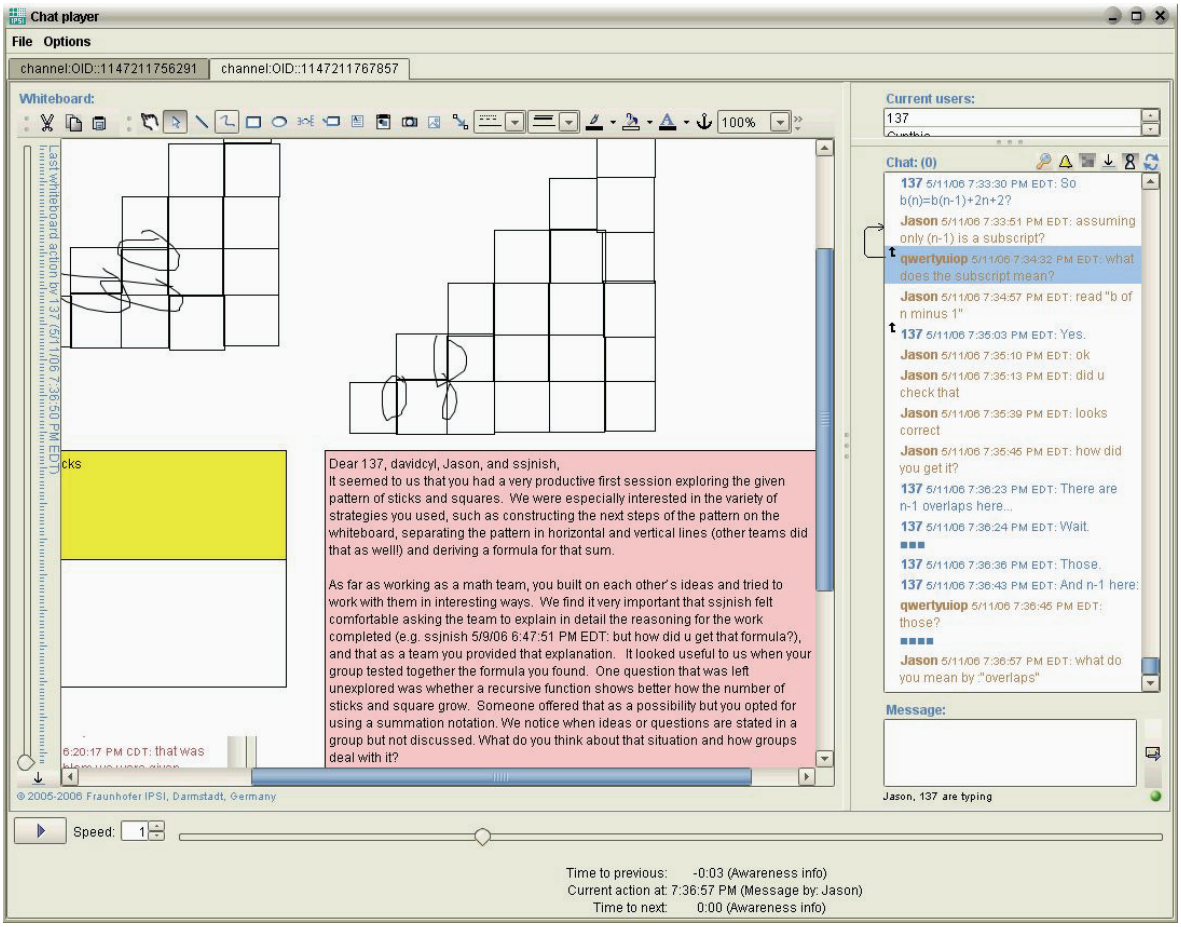

Figure 1. The VMT Chat environment of the session

Our analysis focuses on a 12-minute excerpt of three students doing math problem solving collaboratively in an online chat environment. This is a rich episode of interaction, where a series of questions and responses are produced. We show that questioning and responding plays an important role in productive collaboration and knowledge building in a variety of ways. Some questioning/answering practices have better potential to engage the group in activities that are more consequential for their collaborative experience. For example, the longer sequence of question-answer-test-assessment is significant for learning. Our example analysis below demonstrates that the question, "*How did you get it?*" played an educationally significant role in the group's collaboration and problem solving. It initiated the production of an account, which organized participants around it and engaged them in collaborative meaning making, and eventually led them to the proposal of an alternative approach to solving their problem.

Data Analysis

The data for this analysis is an excerpt taken from a Spring Fest 2006 session of the Virtual Math Teams (VMT) service at http://mathforum.org/vmt. Teams consisted of 3 or 4 middle-school and high-school students who participated in four sessions over two weeks in an experimental online chat environment. The interactions including conversations and other activities are preserved in the system for later access and examination. As a group, they work on a problem that requires them to find out the pattern of growth of a series of figures made of sticks forming squares like the ones displayed in Figure 1. The particular team in the following excerpt consists of three students from different parts of the US. This excerpt is near the beginning of

their second session, which is split into three parts for the convenience of presenting our analysis. Two participants with screen name 137 (replaced by dave in the transcript and analysis to avoid confusion with line numbers) and Jason have participated in the first session and qwer is a newcomer for this session. In this online environment, neither the participants nor the researchers know anything about each other (age, gender, etc.) except what is revealed during the chat. Figure 1 is a screen shot of the replayer tool that reproduces this episode as it originally appeared to the participants. The VMT environment consists of a chat program and a shared whiteboard with drawing functions. The system also provides an explicit referencing tool for connecting particular postings and objects on the whiteboard. The replayer tool has extra information at the very bottom, which participants did not see in their environment. With this tool, researchers can replay a session in real time and be able to watch how interaction unfolds, which makes possible detailed and precise analysis.

How question and response are designed

In the first section of the selected excerpt (Figure 2), we see how a question and response are designed and produced by the participants to be understood *as* a question and its response. Participants understand a question or response by incorporating available resources such as the setting of the interaction, what happened in the past, what has been posted, what the question or response seems to be projecting, and so on.

Line#	Participant	Chat posting	Time	Explicit reference
362	Jason	so apparently there's something with a recursive sequence that we should discuss	07.26.32	
363	dave	What was a recursice sequence again?	07.26.55	
364	qwer	recursive sequence?	07.27.03	Reference to 362
365	Jason	i think that an explicit formula is better, but a recursive one would show how the number of squares/sticks increases as N increases	07.27.18	
366	Jason	it's something like this:	07.27.35	Reference to 364
367	Jason	a(n) = 5+ a(n-1)	07.27.45	
368	Jason	where the things in parentheses are supposed to be subscripts	07.27.53	
369	Jason	so a recursive formula relies on the value of a previous function	07.28.07	
370	dave	Ah, I see.	07.28.09	Reference to 365
371	Jason	thus, you must specify something first, like a(1) = 4	07.28.19	
372	qwer	i get it	07.28.29	Reference to 369
373	Jason	great :-)	07.28.54	

Figure 2. Part 1 of the excerpt.

This excerpt is taken from near the beginning of the second session of this group. In the first session, that took place two days ago, the group worked on the problem and produced the general formula for the total number of sticks and squares at stage N. Feedback has been provided for their first session and posted in a pink textbox on the whiteboard by the VMT facilitators (see Figure 1), which the facilitator of this session has oriented the participants to. With the prompt of the facilitator, the two participants who attended the first session were trying to bring the newcomer, qwer, "up to speed." Jason's posting at 362 marks that they finished the catching-up with "so," and proposes something for the group to do next, namely to discuss "something with a recursive sequence." This would resume what the group was oriented to at the very beginning of the session, "ok, so with this aside—i guess we should discuss our feedback from the last session" (posted by Jason at timestamp 07.12.07).

At this point, we encounter the first instance of questioning in this excerpt in line 363 and 364. There was about half a minute silence after Jason's proposal at line 362 before the next posting of dave appears, during which Jason started typing, and shortly after, dave and qwer started typing, as indicated by the awareness information provided by our replayer software. When a proposed task for the group is put forward, it calls on the participants to respond. To be able to respond to a proposal (and for that response to be seen as in some sense legitimate), one has to be entitled to respond, that is, one needs to be recognizably in a position of being able to understand it, assess it, agree with it or disagree, which organizes the subsequent actions accordingly. In this case, both dave (at line 363) and qwer (at line 364) respond to the proposal with postings designed to be read as questions regarding "recursive sequence." The two postings are designed somewhat differently. dave's posting "what was a recursice sequence again?", uses the past tense "was," the word "again," and a question

mark to display that it is to be read as a question calling on readers to respond. This indicates that there is a shared history of some sort in the group and that dave previously knew about recursive sequences but may not remember at the moment.(1) The way dave's question is designed is different from a question like "What is a recursive sequence?" in that they call for different response actions: the former may only need some information to "remind" him what it is while the latter demands information of the concept of recursive sequence that would help someone who does not know about it at all. The immediately subsequent posting at line 364 could be seen as (1) an other-initiated repair of dave's misspelling ("recursice" vs. "recursive") or (2) an information question that indicates he does not know what a recursive sequence is and is seeking an explanation. That qwer's posting was presented with a question mark served to indicate that, whatever the source of trouble, some explanation of recursive function was in order. How the questions are treated and taken up by the recipient, here Jason, is what is relevant to the participants and to their interaction. Therefore, that is what is relevant to our analysis as well. Understanding the questioning from the participant perspective requires that the analyst make use of the same sorts of resources as are available to the participants, including the interactional situation and the question and response as locally produced, situated phenomena (Garfinkel, 1967).

The subsequent posting from Jason at Line 365: "i think that an explicit formula is better, but a recursive one would show how the number of squares/sticks increases as N increases" may first appear as a continuation of his posting at line 362 and not as a response to either of the questions.(2) When we examine more closely and turn to our replayer to replay the session and watch the interaction unfold, the awareness information shows that after Jason's first message was posted, Jason started typing before dave and qwer. Also, taking into account the fact that Jason's posting at 365 is relatively lengthy so that it may very likely take more than 15 seconds (as suggested by timestamp 07.27.18 and 07.27.03) to compose, it is reasonable to believe that Jason's posting is not produced to address the two questions that appear to be immediately preceding. Nevertheless, the order that the postings actually appeared on the screen could be taken by participants as a reason to treat Jason's posting as a response to the question.

If we take into consideration the setting where the interaction takes place, we know that it is a kind of institutional setting, set up by VMT staff through teachers. The group had met once before (two days ago) and did some work on the same problem. In response to that work, VMT staff posted feedback for that prior session on the shared whiteboard. The students are now oriented to discussing the feedback. With all this in mind, Jason's posting at Line 365 seems to be referencing and responding to what has been raised in the following part of the feedback: "*One question that was left unexplored was whether a recursive function shows better how the number of sticks and square grow. Someone offered that as a possibility but you opted for using a summation notation. We notice when ideas or questions are stated in a group but not discussed. What do you think about that situation and how groups deal with it?*"

Sequences of action are performed in ways that contribute to the progression of the interaction in a methodical sense (Stivers and Robinson, 2006; Schegloff, 2007). In this sense, the silence after Jason's first posting and the questions posted by dave and qwer interrupt the progression of interaction and thus make relevant actions to restore the unproblematic progression of interaction. Rather than simply proceed with the trajectory of work projected by his initial posting at line 362, Jason produces postings (lines 365 through 369) designed to further his discussion in a way that also responds to the questions posed by dave and qwer. In order for these postings to be constituted as a response to the questions of dave and qwer, the author of the explanation (Jason) and the recipients for whom the explanation is produced (dave and qwer) must do some work. This is necessary to establish common ground among the interactants (Clark & Brennan, 1991).

The posting from dave ("Ah, I see.") with explicit reference to one of Jason's postings as well as that from qwer ("i get it") indicate their engagement in such processes and that they are doing the work of communicating to Jason their understanding of his explanation. Such responses are acknowledged by Jason ("great") with a smiley face emoticon. At this point, the question-response adjacency pair is complete and the group is ready to move on to subsequent action.

How questions are used to organize participation

374	qwer	for the number of squares, would that be: a(n)=n2-1	07.30.07	
375	dave	so a(1)=1, a(n)=n+a(n-1)...	07.30.15	Reference to 371
376	dave	For squares...	07.30.18	
377	Jason	it looks right... lets check for a few values of N	07.30.39	Reference to 376
378	Jason	when N = 1, #squares = 1	07.31.06	
379	dave	When N is 2, a is 3.	07.31.19	
380	Jason	yup, i think thats right	07.31.22	
381	dave		07.31.47	

382	dave	Oops.	07.31.52	Reference to 381
383	dave	b(1)=4, b(n)=b(n-1)+4(n)-(n-1)-(n-1), b is the number of sticks...	07.33.06	
384	dave	So b(n)=b(n-1)+2n+2?	07.33.30	
385	Jason	assuming only (n-1) is a subscript?	07.33.51	
386	qwer	what does the subscript mean?	07.34.32	Reference to 385
387	Jason	read "b of n minus 1"	07.34.57	
388	dave	Yes.	07.35.03	Reference to 385
389	Jason	Ok	07.35.10	

Figure 3. Part 2 of the excerpt

When a question-response adjacency pair is done, the actors can move on to other matters, or follow up on what has been provided as a response, which seems to be what happened in this excerpt. The next posting at Line 374 by qwer appears more than one minute later in the form of a yes/no question: "for the number of squares, would that be: a(n)=n2-1". By producing this posting as a question (as indicated by its grammatical construction), qwer "performs" his understanding of Jason's explanation in a way that calls on recipients to assess his treatment of recursion as explained by Jason. By calling for assessment of his application of a recursive sequence to the problem, qwer calls on recipients to evaluate that understanding and possibly diagnose any problems with it. Dave's next post is produced as an assessable conclusion regarding the formula for the number of squares that is presumably derived from Jason's explanation of recursion. Dave's posting appears to be in a more complete form, considering the form of recursive sequences as just explained. About 20 seconds later (which is a relatively large elapse in online chat), it received an endorsement from Jason, "it looks right…", who, in the same post, proposes that it be checked for validity with "a few values for N" (Line 377). The proposal by qwer is not taken up in the subsequent actions of the group.

The ways that online chat is organized are interactionally different from face-to-face interaction (Garcia & Jacobs, 1999). In a face-to-face situation when dyads are conversing, the turn-taking rules mandate that one interactant's utterance ought to be taken up in order to produce meaningful interaction; so it is hard to ignore someone's utterance in face-to-face interaction. However, in an online chat environment like VMT Chat, more than two participants are "conversing" by exchanging text postings and through activities on the whiteboard. The pace of interaction usually is fast, and participants need to orient most of their attention simultaneously to various activities going on, such as keeping track of the flow of the conversation, reading social awareness messages, paying attention to the shared whiteboard when someone is performing some actions, and so on. When three or more participants are posting, one message could be easily ignored simply because of limitations of attention. Further, it is essentially *reading's work* (Zemel, 2005) that they are engaged in with chat environments. Postings serve as resources for them to organize and accomplish interactional work. In other words, a posting calling for response may not be taken up by the group for a number of reasons without disrupting the general smooth progression of interaction.

In our case, dave's seemingly more complete (or more correct) proposal is taken up by Jason, who has been accorded the status of a situated, local authority regarding recursive sequences by dave and qwer who solicited assessments from him. Jason and dave then engage in performing the task proposed by Jason, checking the values of N to see whether the formula holds up. These actions along with Jason's explicit assessment affirm dave's provisional understanding at line 375, and thus implicitly answer qwer's question by treating it as incorrect. Jason's confirmation after the checking work concludes his assessment of dave's candidate formula and serves to provisionally propose the relevance of moving on to a new action. However, dave is not yet finished. Dave's multi-post question in lines 383 and 384 offers a formulaic version of his understanding of recursion and is designed as a question (with a question mark) that calls for assessment.

This question leads to questions from Jason and qwer as response to the call. Jason's question "assuming only (n-1) is a subscript?" is produced to establish a *common ground* (Clark & Brennan, 1991) on their reading of (n-1). Only with the shared understanding of it can Jason be entitled to produce an assessment of the proposal. Qwer's question "what does the subscript mean?" is an information question that seeks clarification of Jason's query in 385. This question is rather interesting if we think about qwer's earlier announcement, "i get it," in responding to Jason's elaborated explanation on recursive sequence, which has a subscript as one of its characteristic components. If we took qwer's statement, "i get it," as an indication that he understood recursive sequences, his question about subscripts would be rather problematic. Maybe it is only meant to be indicating that he "got" why they are using a recursive function. Other interactants—as well as we as analysts—would have no way to know at that moment. This raises the issue of when a question is answered sufficiently, which may have to be left to the subsequent unfolding of interaction to determine.

Our preliminary analysis of this short episode reveals to us the richness of discourse of a small group engaged in collaborative math problem solving. Even in this short episode consisting of 16 postings within 5 minutes or so, we witness various questions being produced during the collaborative problem-solving process. They do various kinds of work, including engaging the participants, organizing their participation framework, establishing common ground, and seeking information. In a sense, the participation and collaboration are organized around the question-response as it unfolds. Questioning also plays an important role in the "understanding" work participants do together. Specifically, participants apply what has been explained to the problem situation and put the proposal out for assessment by asking a question.

A question that leads to productive learning moments

390	Jason	did u check that	07.35.13
391	Jason	looks correct	07.35.39
392	Jason	how did you get it?	07.35.45
393	dave	There are n-1 overlaps here...	07.36.23
394	dave	Wait.	07.36.24
395	dave	Those.	07.36.36
396	dave	And n-1 here:	07.36.43
397	qwer	those?	07.36.45
398	Jason	what do you mean by :"overlaps"	07.36.57
399	dave	They're counted twise; they belong to two boxes.	07.37.17
400	Jason	are you guys still talking about that formula?	07.38.13
401	Jason	because i dont think the overlap in the diagrams matters	07.38.22
402	dave	Yeah...	07.38.23
403	Jason	if you are only calculating the number of sticks	07.38.36
404	qwer	might be easier if you think of each square corisponding to 2 sides-the right and bottom sides, and then add the upper left border	07.39.02

Figure 4. Part 3 of the excerpt

This episode is a continuation of part 2. Dave's proposal on the formula for the number of sticks presented in the form of a question has not yet been assessed as it is designed to be. The participants were engaged in building common ground as a prerequisite for understanding the proposal and being able to make an assessment. Such grounding work has now been completed, so it is finally a relevant matter for the group to attend to the unaddressed call for assessment. This is what Jason is doing at the beginning of this excerpt. He first tries to elicit from the author of the proposal whether some checking has been done. After 26 seconds elapses, Jason provides his assessment: "looks correct". The subsequent question by Jason, calling for an explanation of the proposal ("how did you get it?"), echoes this rather ambiguous comment and positions him as in a status of being not prepared to make a real assessment. This question leads dave to produce detailed explanations, which in this case are done both in text in chat and actions on the shared whiteboard (see Figure 1). The chat area on the right in Figure 1 has little squares between dave's postings, which indicate the activities performed on the whiteboard. When we replay the session in real time, we can see that dave first marked three horizontal sides between squares in the diagram with scribble lines then marked three vertical ones. The deictic and indexical work is achieved by using the word "those", "here", along with directing interactants' attention to the whiteboard where actions are performed (Cakir, Zemel, & Stahl, 2007). The text postings would not make sense on their own if not taken together with whiteboard actions in a coordinated way.

The question "*how did you get it*" thus initiates the process of producing an account of the formula, which bears a lot of resemblance to a mathematical proof in this case. This is also a collaborative meaning-making process, because the participants need to mutually engage and participate in the production of the account to construct meaning of it. The work of producing an account opens up the opportunity for exposing the work that has been done to the scrutiny of the group. It also provides the participant who is doing the production an opportunity to reflect while revisiting the work and producing a coherent account. In fact, during the process where dave is producing an account of his formula, Jason problematizes his approach, which takes into account the "overlaps" by presenting his perspective: "because i dont think the overlap in the diagrams matters" (Line 40). The process is much more complex than a simple question-response pair. We see sub-questions posed

along this process such as qwer's question "those?" and Jason's explicit calling for explanation 'what do you mean by: "overlaps"'. Jason's problematizing move reveals different perspectives among the participants for seeing the problem. This leads to Qwer's proposal of seeing the growth of the pattern in an alternative way, which "might be easier": "might be easier if you think of each square corisponding to 2 sides-the right and bottom sides, and then add the upper left border" (Line 404).

In the subsequent interaction, which is not shown in the excerpt, qwer is able to produce a correct formula for the number of sticks based on his proposed perspective of seeing the pattern of growth. This is rather a surprising achievement considering that for the whole time from the very beginning of the session, qwer has not demonstrated high competency in working on this particular problem and has not made any significant contribution to the group's problem-solving progress. However, he has shown that he has been trying hard to follow and participate, e.g., from the number of questions he has posed at particular times of the interaction sequence. From the analysis, we see that the question "*how did you get it*" has played an educationally significant role in the group's collaboration and problem solving. It initiates the production of an account, which organizes participants around it and engages them in collaborative meaning making (Stahl, 2007), and eventually leads to the proposal of an alternative approach to solving the problem.

Discussion

Questions and responses are used to perform a variety of actions depending on their design and the circumstances of their use. In the episode we have just analyzed, questions posed by participants in a small group do various work in their collaborative problem solving. Our preliminary analysis has shown how questions are used for organizing participation, coordinating group process, establishing common ground, seeking information, doing understanding work, etc. Often one question does multiple kinds of work. Questions provide various resources in their design and production that reify epistemic relations among participants. They are performed in ways that constitute actors as participants of various sorts, i.e., determining who can ask questions and who is entitled to respond. Questions situate actors in a scene in relation to each other by making evident who acts, of what those actions consist, and the provisional entitlements of actors to participate in the performance of those actions. The entitlement to produce questions and responses is a matter of interactional significance to participants. Questions play an important role in participants' understanding work. In the episode we have just analyzed, participants apply what has been explained to the problem and make a proposal in the form of a question to call for assessment. By putting out one's understanding for assessment, participant can get feedback. This may reveal problems of understanding if there are any.

Questions and responses do not just happen. There are various methods participants use to design and produce a question. Participants make use of various available resources to make evident to each other the adequacy of the question and response, e.g.: the shared history of the group, what has happened in the session recently before, what possibilities for response the previous action projected, awareness information of the production of an action, the existing postings and activities performed on the shared whiteboard, etc. In the VMT chat environment, postings are not meant to be "heard," but "read." The texts in the chat and artifacts on the whiteboard are contingent, situated and produced to be interactional resources. A question on its own would not make sense to participants nor to researchers unless put in the local context and treated as a locally produced situated social phenomenon. It defines its meaning through the interaction among participants, and is interactionally accomplished.

The uniqueness of the interactional setting built up as the interaction takes place is consequential for how participants produce questions and responses and make sense of them. In the VMT environment, the shared whiteboard, the referencing tool and the social awareness information accord participants resources for organizing their interaction and participation. The chat and whiteboard are used in a coordinated and integrated way to produce the explanations a question is calling upon. The fact that there are more than two participants and interaction is mediated in a chat environment shapes the way interaction takes place. Our analysis shows that a question-response pair often takes more than two or three turns to complete. Questions often lead to sub-questions that call upon sub-responses—a question-response pair can have nested sub question-response pairs.

Our analysis has revealed in particular that questions calling for accounts of problem-solving work are different from "pure information questions" as traditionally conceived. They are not simple inquiries where sought information is directly provided as some static object. Rather, they call on elaborated explanations. In the third part of the excerpt, for instance, in response to the question, "how did you get it?", dave engages in producing an account of the formula he proposed. As participants collaboratively engage in such productions of accounts, they make meaning of proposals together. Such questioning initiates a potentially educationally productive episode of collaborative problem solving. Although the questioning actions analyzed in this paper are utterly situated and must be analyzed as a unique case study focused on interactional sequentiality, we have found the structure of such practices of questioning to be typical within our corpus of online math discourse. Making math proposals, raising questions, responding with nested questions, providing accounts and reaching

conversational transitions are driving mechanisms for the interactional progression among students in the virtual learning world created by the VMT project.

Endnotes

(1) Some information that seems to be relevant here is that the group did encounter the idea of using recursive sequences brought up by one of the participants in the previous session and the concept of recursive sequence was not problematic at the time.

(2) It is well known that in an online chat environment like this where more than two participants are interacting, the turn-taking rules for face-to-face interaction with dyads do not apply directly (Garcia & Jacobs, 1999). The characteristics of different "turn-taking" mechanism can result in confusion both for participants and researchers when examining the sequence of postings in chat (Herring, 1999).

References

Clark, H. & Brennan, S. (1991). Grounding in communication. In L. Resnick, J. Levine & S. Teasley (Eds.), *Perspectives on socially-shared cognition* (pp. 127-149). Washington, DC: APA.

Çakir, M. P., Zemel, A., & Stahl, G. (2007). The organization of collaborative math problem solving activities across dual interaction spaces. Paper presented at *the International Conference of Computer-Supported Collaborative Learning (CSCL '07)*, New Brunswick, NJ.

Fox, B. (1993). *The human tutorial dialogue project*. Hillsdale, NJ: Lawrence Erlbaum.

Garcia, A. and Jacobs, J. B. (1999) The Eyes of the Beholder: Understanding the Turn-Taking System in Quasi-Synchronous Computer-Mediated Communication. *Research on Language and Social Interaction*, 32, 4, 337-367.

Garfinkel, H. (1967). *Studies in ethnomethodology*. Englewood Cliffs, NJ: Prentice-Hall.

Graesser, A. C. & Person, N. K. (1994). Question asking during tutoring. *American Educational Research Journals*, 31(1).

Graesser, A. C., Person, N. K., & Magliano, J. P. (1995). Collaborative dialogue patterns in naturalistic one-to-one tutoring. *Applied cognitive psychology*. 9 (6), pp. 495-522.

Herring, S. (1999). Interactional coherence in CMC. *Journal of Computer Mediated Communication, 4* (4).

Mehan, H. (1979). *Learning lessons: Social organization in the classroom*. Cambridge, MA: Harvard University Press.

Roschelle, J. (1996). Learning by collaborating: Convergent conceptual change. In T. Koschmann (Ed.), *CSCL: Theory and practice of an emerging paradigm*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Scardamalia, M., & Bereiter, C. (1991). Higher levels of agency for children in knowledge building: a challenge for the design of new knowledge media . *The Journal of Learning Sciences*, 3(3), 265-283.

Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *The Journal of Learning Sciences*, 3(3), 265-283.

Sacks, H. (1992). *Lectures on conversation* (Vol. 1&2). Oxford: Blackwell.

Sacks, H., Schegloff, E., & Jefferson, G. (1974). A simplest systematics for the organization of turn-taking in conversation. *Language, 50*, 697-735.

Schegloff, E. A. (2007). *Sequence Organization in Interaction: A Primer in Conversation Analysis*. Cambridge, UK: Cambridge University Press.

Schegloff, E. A., Jefferson, G., & Sacks, H. (1977). The Preference for Self-Correction in the Organization of Repair in Conversation. *Language, 53*(2), 361-382.

Stahl, G. (2006b). *Group cognition: Computer support for building collaborative knowledge*. Cambridge, MA: MIT Press.

Stahl, G. (2007). Meaning making in CSCL: Conditions and preconditions for cognitive processes by groups. Paper presented at *the International Conference of Computer-Supported Collaborative Learning (CSCL '07)*, New Brunswick, NJ.

Stivers, T., & Robinson, J. D. (2006). A preference for progressivity in interaction. *Language in Society, 35*, 367-392.

Ram, A. (1991). A theory of questions and question asking. *The Journal of Learning Sciences*, 1(3/4), 273-318.

van Zee, E. & Minstrell, J. (1997). Using questioning to guide student thinking. *The Journal of Learning Sciences*, 6(2), 227.

Webb, N. M., Nemer, K. M., & Ing, M. (2006). Small-group reflections: parallels between teacher discourse and student behavior in peer-directed groups. *The Journal of Learning Sciences*, 15(1), 63–119.

Webb, N. M., Ing, M., Nemer, K. M., & Kersting, N. (2006). Help seeking in cooperative learning groups (pp. 45-88). In R. S. Newman and S. A. Karabenick (Eds.), *Help Seeking in Academic Settings: Goals, Groups and Contexts*. Erlbaum.

Wells, G. (1999). Dialogic inquiry: Towards a sociocultural practice and theory of education. NY: Cambridge University.

Zemel, A. (2005). Texts-in-interaction: Collaborative problem-solving in quasi-synchronous computer-mediated communication. Paper presented at *the International Conference of Computer-Supported Collaborative Learning (CSCL 05)*, Taipei, Taiwan.

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