Towards Building a Math Discourse Community: Investigating Collaborative Information Behavior

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Abstract. We reported a study that analyzes collaborative information behavior of small groups in an online math discourse community. Taking group as the unit of analysis, we analyzed the social interactions of participants engaged in collaborative math problem solving and examined how they seek for information in such context. Participants look for information oriented to the procedure, problem, context, and social aspects. Various resources and methods are observed being used by participants to satisfy their information needs. These findings help us understand social interactions and online communities.

Keywords: Collaborative Information Behavior, Online Community, Computer-Supported Collaborative Learning, Conversation Analysis

1 Introduction

Recent years have seen the growing emergence of online communities of various purposes and forms of organization. Developing online communities involves two issues: usability and sociability [1]. While usability concerns how human interact with computer technology, sociability is more concerned with supporting social interaction. More research is still need to understand online communities especially the social interactions to address the sociability issue, which is important for designers in order to develop healthy and sustaining online communities. This calls for a closer examination of participants' practices within the communities.

Participants of online communities often engage in all sorts of information seeking and information sharing activities, especially in communities with educational purposes. Information behavior has been a topic of central interest of information science. Though lots of research has been conducted on understanding human information behavior in various contexts [2],[3],[4],[5],[6], collaborative information behavior is relatively less studied and thus not very well understood. In this paper, we report a study that analyzes information behavior of small groups of young participants (6-12 graders) in an online community engaged in math problem solving collaboratively. The study is situated in a larger research agenda of the *Virtual Math Teams* project[1], an on-going research effort conducted to evolve an online math

[1] www.mathforum.org/vmt

discourse community. Researchers from different disciplines (including information science, math education, anthropology, communication, etc) are working together designing a service extending the Math Forum's[2] Problem of the Week service to support collaborative learning and knowledge building [7] within this community. A central research aim of the project is to develop a systematic understanding of how math discourse takes place in an online chat environment [8].

In the study presented in this paper, we focus on analyzing collaborative information behavior of small groups within the VMT virtual environment. More specifically, we have looked at how participants in a small group negotiate and construct their information needs when engaged in math problem solving. We have examined what information they are looking for, what resources they use to find the information, and how they satisfy their information needs. These findings will be presented through detailed micro-level data analysis of a few short example excerpts. We then discuss the findings and their implications for building online communities.

2 Data Collection and Research Methods

We believe students can learn math better and more effectively when they talk about math with their peers. Bringing learners together can challenge them to understand other people's perspectives and to explain and defend their own ideas. It also helps to stimulate and build important comprehension, collaboration and reflection skills. The VMT project offers K-12 students such an opportunity by providing chat rooms for small groups of them to meet online and discuss math. Such discussion is organized as one hour long session, where 3 to 5 students in one chat room are provided a math problem that is designed to stimulate mathematical thinking. One facilitator will be there to get them started but it is up to the group to figure out the math. We have conducted around 50 sessions under naturalistic setting using online synchronous environments, from *AOL Instant Messaging* (AIM) early on to *VMT Chat*, a sophisticated chat environment specifically designed for the needs of the community. The *VMT Chat* provides a shared whiteboard with drawing facilities and features such as referencing tool that participants can use to make explicit reference to text postings and objects on the whiteboard. The conversations and other activities are preserved in the system for later access or examination.

Ethnomethodology, founded by Garfinkel [9], is a branch of sociology that studies the routine ways by which actions, including talk-in-interaction, are performed to constitute the intersubjective reality of social life. Harvey Sacks [10], who worked closely with Garfinkel, developed a related methodological approach for the close analysis of ordinary talk-in-interaction called *conversation analysis*. We have applied an ethnomethodologically-informed approach that combines aspects of conversation analysis and ethnomethodolgy to analyze information practices of participants within the VMT virtual community. This approach stresses close examination of interactional data at a micro level, to identify and describe the observable methods participants use to make sense of their interactions for themselves and each other.

[2] www.mathforum.org

3 Data Analysis and Findings

In this section, we show our analysis of a few sample excerpts from participants' transcripts which demonstrate different aspects of information behavior of VMT participants. Taking the group as the unit of analysis, we've approached analyzing the data from an interactional perspective and looked closely at the social interactions taking place within the group.

3.1 Seeking Information to Make Sense of the Surroundings

A typical VMT chat session usually opens like what we can see in the following excerpt of transcript: participants log in the room and greet each other. Usually there is a facilitator present in the room to get participants started on working on the problem. In the following excerpt that lasts less than 2 minutes after the second participant (bwan) joined, we can see the unfolding of the interaction. Facilitator "Gerry" started by greeting everyone and identified himself as the "VMT guide". A participant with the handle name "Aznx" had the question regarding the identity of the person who appears as "Gerry". Bwan responded to the question using his own vocabulary and recognized "Gerry" as an admin (short for administrator). Gerry continued to provide information to the participants: the goal of today's session is "mainly to get to know the VMT system". There is also a comment on the rules or norms of the session "*So we can't have our own friends*" and information provided on identifying participants themselves: "*hey three of us are from miller*". By greeting each other, identifying each other, and establishing the goal of the session, along with using abbreviation (lol, which usually is used as short for "laugh out loud") and emoticon (=)), the interaction unfolds in a friendly and lighthearted way and participants organize themselves into a position that is ready to move on to the next step of the session.

Line #	Handle	Message	TimeStamp
1	Gerry	joins the room	06.17.35
2	bwan	joins the room	06.23.13
3	Aznx	joins the room	06.23.14
4	Qsilver	joins the room	06.23.14
5	bwan	hi	06.23.18
6	Aznx	Hi	06.23.23
7	Qsilver	hey	06.23.28
8	Aznx	So we can't have our own friends?	06.23.35
9	bwan	nope	06.23.40
10	bwan	lol	06.23.49
11	Qsilver	hey three of us are from miller	06.23.52
12	Gerry	Hi everyone!	06.23.55
13	bwan	oh	06.24.03
14	Gerry	I am your VMT guide today	06.24.06
15	Aznx	How?	06.24.06

16	Qsilver	nvrmind	06.24.12
17	Qsilver	two of us	06.24.13
18	Aznx	Who's Gerry?	06.24.13
19	bwan	admin	06.24.19
20	Aznx	Yeah. =)	06.24.19
21	Qsilver	Hello Gerry!	06.24.45
22	Gerry	Today's session is mainly to get to know the VMT system	06.24.59

Excerpt 1.

As a new user of the system, one thing that probably is noticeably different about the environment from other chat systems is the whiteboard with drawing functions and other features. Coming into such an environment they are not familiar with, participants usually explore the system and get themselves oriented. They need to find out how to get around the system, how to use certain functionalities, etc. In order to satisfy these information needs, participants either try to figure out by experimenting by themselves or seek help from the group, including the peer participants and the facilitator. By identifying himself as "VMT guide" of the session earlier, Gerry positions himself as someone who knows better about the system than other participants and thus will be able to provide information regarding the use of the system. This identity and position has been acknowledged by the participants (e.g. bwan told Aznx that Gerry is the admin), which put them in the position of information seeker. In line 23, Aznx posed a question regarding how to use the whiteboard, whereas bwan started making reference to the whiteboard as a step of exploring how to use it.

23	Aznx	So, how do you use the whiteboard?	06.25.18	
24	Gerry	I will answer your questions as you start to do things	06.25.51	
25	bwan	asdfadsf	06.25.59	Reference to whiteboard
26	bwan		06.25.59	
27	bwan	ok	06.26.15	
28	Gerry	The whiteboard is a shared area for drawing and textboxes	06.26.27	

Excerpt 2.

Along the session, after participants are oriented to their task, they encounter the need for information on using the system from time to time. Participants frequently engage in such information seeking and information giving in their interactions.

3.2 Negotiation of Information Needs

One important type of information participants in a VMT chat session frequently find they are in need of is that related to solving the problem, which may include certain math information, and strategies or resources for tackling the problem. Facing a math problem, participants usually need to do the work of understanding the problem, identifying what is known and what they need to know in order to solve it. Such work

is accomplished collaboratively through the interactions within the group. Participants often achieve the identification of information needs by negotiation. In the following excerpt, three participants (two 9 graders and one 11 grader) are working on a geometry problem:

> *If two equilateral triangles have edgelengths of 9 cubits and 12 cubits, what's the edgelength of the equilateral triangle whose area is equal to the sum of the areas of the other two?*

This example demonstrates the process of negotiating the information needs for solving the problem, which in this case happens to be a smooth one. AVR starts identifying what they need to know by proposing that they should "start with the formula for the area of a triangle". This is acknowledged by SUP. AVR continues by providing the formula. By putting this information out, followed by "I believe", AVR is calling for assessment from other participants. PIN indicates his explicit agreement with AVR's proposal and information being provided by saying "yes", "i concur". Instead of providing an agreement, SUP starts moving to the next step as finding the base and height, which the formula is built upon. By making such movement, SUP implicitly accepts what AVR is proposing. This short process of negotiation establishes the need of the group regarding solving the problem.

AVR	Okay, I think we should start with the formula for the area of a triangle	8:21:46
SUP	ok	8:22:17
AVR	A = 1/2bh	8:22:28
AVR	I believe	8:22:31
PIN	yes	8:22:35
PIN	i concue	8:22:37
PIN	concur*	8:22:39
AVR	then find the area of each triangle	8:22:42
AVR	oh, wait	8:22:54
SUP	the base and heigth are 9 and 12 right?	8:23:03

Excerpt 3.

3.3 Seeking Information on Math Problems

We prefer the term information inquiry than information seeking question because of the fact that a posting not formulated in the form of question can sometimes be treated as seeking information. It is the way a posting is read and treated by the group that makes it recognizable as an inquiry for information from an analytical and interactional point of view. This is also how an information inquiry is made publicly visible and recognizable through the interactions to us as researchers. Many information inquires take the form of a question that seeks an answer which is information with relatively fixed boundaries. For example:

> HOL: do you know the equation to find area of a cylinder?
> AME: BaseArea times height

The question of HOL is clearly read as a call for information. The answer to the "do you know" question could legitimately be "yes, I do". But by recognizing it as seeking for information, AME provides the equation "BaseArea times height" in

response to the question. In other cases, a posting may not appear as an information seeking question if judged from the form it is taking. It is however taken up by other participants as information inquiry and consequentially results in the action of providing information. The following excerpt (4) is from the same chat session as Excerpt 3. AVR's posting in the first line can be read as proposing what the group needs to do. From how it is responded by the other two participants PIN and SUP, the posting is doing the work of organizing the group to think about how to find the height: both PIN and SUP propose their way of finding the height, which is in a sense treating AVR's posting as a *how* question, that is, "how do we figure out the height?". PIN's response "I know how" brings AVR's interest in finding it out. By asking "how?", AVR shifts her position to one seeking information from the one (PIN) who claims to have the information to give. It needs to be pointed out that the sequence that postings appear in a chat environment may be distorted from the sequence of postings being composed and posted due to the nature of computer-mediated synchronous communication [11]. More than one participant could start "talking" at the same time due to the different turn-taking mechanism afforded by such communication and the time one utterance gets posted depends on the time it arrives the server that handles the messages. This is what happens in line 62 and 63, which have exactly the same time stamp. AVR asks "how" at line 64 clearly because she hasn't seen PIN's posting on line 63. This short excerpt demonstrates how a posting that doesn't appear in the form of a question can also be an information inquiry from an analytical point of view.

60	AVR	i think we have to figure out the height by ourselves	8:23:27
61	AVR	if possible	8:23:29
62	PIN	i know how	8:24:05
63	PIN	draw the altitude'	8:24:09
64	AVR	how?	8:24:09
65	AVR	right	8:24:15
66	SUP	proportions?	8:24:19

Excerpt 4.

In the next five minutes or so into the chat, the participants take up PIN's proposal on how to find out the height and go about actually "finding it". At 8:27:17, PIN asks "anyone remember formula for 30/60/90 triangle?" as a clear question seeking the formula from the group. The notion of 30/60/90 triangle is questioned by the other two participants and they decide they are dealing with 60/60/60 triangle. The following excerpt shows an information inquiry seeking a formula (line 108) is put on the table, which calls the response and action of other participants. AVR admits her deficiency of knowledge on this manner ("I have no idea") but acknowledges the usefulness of such information (line 110). The first attempt to seek information from the group fails. A proposal to turn to external resource is brought in by PIN: "search google", which is reified by AVR's action: "that's what I'm doing".

108	SUP	is there a formula for a 60/60/60?	8:29:04
109	AVR	I have no idea	8:29:12
110	AVR	I think once we find the formula it should be pretty easy	8:29:20
111	AVR	I don't think there's a formula, though	8:29:24

112	PIN	search google	8:29:27
113	AVR	I think we find it some other way	8:29:29
114	AVR	that's what I'm doing	8:29:31

Excerpt 5.

This practice is commonly observed in such collaborative sessions where participants work together to solve a problem. They usually take the group as a primary resource for information and often first turn to the group for help when encountering an information need. If the group is not able to provide the needed information, they may use external resources such as online search. This is what happens in this particular example as we discussed above.

3.4 Seeking and Providing Personal and Contextual Information

When participants in a group are communicating in a chat environment and trying to accomplish the task, all the interactions are achieved through the text postings, drawings on the shared whiteboard, awareness messages, etc., whatever is made available and visible for them in the system. Being in such a virtual environment, people are technically interacting with messages and activities shown on the screen. They are doing so because they are aware that there is a real person they are interacting with. In a virtual community, the feeling of social presence and co-presence [12] is important for meaningful communication. Participants engaged in a chat session often need information about others being present for establishing identify or for the sake of socializing. They employ different methods to find out what they need to know as well as provide information to others. This usually happens sometime into the session or after they worked on the problem for a while. In the following chat excerpt, REA is asking PIN a question about his math level. Immediately prior to this conversation, REA proposed that they "might have to use law of sines", which PIN reckoned that (his class) "haven't learned yet". This brought up PIN's inquiry on what it (law of sines) says and the two participants MCP and REA both provided their version of the law of sines. After this little episode of information inquiry and information giving, it seems natural that REA wants to find out PIN's math level, which is what is taking place in the following excerpt.

REA	where are you in math	8:56:12
PIN	uhh	8:56:28
PIN	like level?	8:56:38
REA	yeah geo., alge, or algebra 2	8:57:11
PIN	ohhh	8:57:15
PIN	geometry honors	8:57:19
PIN	freshman	8:57:27
REA	what grade	8:58:03
PIN	9	8:58:13
REA	i am in 6 th	8:58:28
REA	grade	8:58:32

Excerpt 6.

REA also provides information of his own grade level as a reciprocal action, which makes such information exchange recognizable as socializing. This brief moment of socializing may help establishing their identity to each other and thus bring the sense of co-presence in such a virtual environment. Participants therefore can feel that they are interacting with real people and build the feeling of being in a community. A few minutes after this episode, the two participants PIN and REA along with the third one MCP had casual chat on their school life and the tests they will be dealing with. Something noticeable is that REA explicitly calls MCP to check his presence, which is a message to invite him into this socializing conversation.

Teenagers nowadays in the US are a generation brought up with computer technologies. They are very apt users of online chats. There are certain practices and conventions that have been developed for online chatting within this young population. Naturally the participants at VMT bring in such practices and norms they are already familiar with. Among those, some are methods of seeking and providing information to construct the context of interaction and feeling of co-presence. Emoticons and abbreviations are frequently seen being used in the chat as ways to convey emotions and tones to the text posting. Participants also use ** to quote a message that describes to the group what one is doing. For example:

AVR	**begins to scribble on paper**	8:20:36
AVR	or should I not do that?	8:20:47
PIN	doesnt matter	8:21:11
AVR	got it	8:21:25
AVR	**proceeds with scribbling..**	8:21:31

Excerpt 7.

Providing such contextual information is important not only because it builds the sense of presence but also plays significant roles in facilitating the collaboration process by bringing the group up to date of one's status in working on the problem.

4 Discussion of Findings and Implications

Procedure-Oriented Information. When participants come to the VMT environment and work with their peers on math problem solving, their goal is to do the math in a group and have fun doing this. This is done by interacting with other participants through the particular environment. They first of all need to orient themselves to the environment and the task, that is to say, they have to make sense of their surroundings to be able to do the collaboration and problem solving. For most participants, the task of discussing math in a chat environment and work collaboratively on solving a math problem is relatively a new thing which they are not familiar with. Usually a facilitator is there to provide participants information on what they are supposed to do, procedures of the task, some technical issues of using the system, and norms of doing the chat. For example, the facilitator would say: "Here are four guidelines that we'll use tonight.1. During the session, share ideas about how to solve the problem...". Participants find out the information they need to make sense of the environment and the task by asking questions or experimenting the functionalities on their own.

Problem-Oriented Information. This is mainly about mathematics information. Since the main purpose of participants being here is to explore math problems together, the need for math information is often prominent during the process. Given the problem, they need to identify from the problem description what is known and what they still need to know. Such needs are negotiated and constructed together collaboratively. There are different resources participants use to seek information to satisfy the identified needs. The group they are working with is always one primary resource they seek help from. Very often, they turn to external resources such as google or the Math Forum online resources ff the group is not able to provide needed information. They also try to use their previous work in VMT or what's learned before in class: "What can we use that we already know?", "using the formula from yesterday's problem", "Since we're both in Spanish class, are you saying something what the Aztecs made?".

There are different methods observed participants use to seek information. Some information inquiries are in the form of a straightforward question such as "what does itmeans by edglengths?[3]" or "do you know the equation to find area of a cylinder?". Some postings in the chat do not appear in a question but they are taken up and treated by others as information inquiries. Some of them are formulated as a call for proposals, which are responded by participants with proposing strategies or information. Sometimes they result in actions taken in finding needed information. Participants also ask an information seeking question along with providing an alternative answer, which calls for assessment work of the group. Sometimes participants seek information by providing information. These methods are important for doing social interaction and collaboration thus worth closer examination.

Context-Oriented Information. During the collaborative session, participants need to constantly make sense of what is going on around them. They need find information to establish others' identity. They need information on the status of the work to keep themselves updated. A question like "bwang, what are we doing?" is seeking such information so the participant can be in sync with rest of the group. Participants are also quite apt at providing contextual information to others. Such information seeking and giving help making the collaboration process smooth.

Socially-Oriented Information. Apart from doing problem solving, participants sometimes also go "off topic" and socialize. They want to find out more about people they are interacting with. They are interested in finding out what math level and which grade the other is in, where the person is from, the school life, and math experience, etc. Socializing is an important and necessary part of the conversation from the perspective of evolving a community. Information about the participants helps to build the identity in the community and increase the sense of social presence. This finding encourages us to explore the need of building user profiles and what information to include in them. It helps us to recognize participants' needs for socializing and make us think how they should be supported by our facilitation. We want to create an environment where participants can fulfill what they want to do and have enjoyable experience of doing math collaboratively. This environment also needs to be safe for our young users, maybe by protecting their personal information.

[3] All the quotes are original from transcripts of VMT sessions.

and identity. It still remains a question how to develop policies for such community that would meet users' needs but also satisfy other goals such as safety.

Conclusions. In this paper, we presented our analysis of collaborative information behavior of an online math community where small groups of participants are working on solving math problems together. We looked closely at their social interactions and identified what information participants are looking for, what resources they use to find the information, and how they achieve these. By analyzing what activities participants do in such environment, we are able to understand better their information and social practices. Participants have various information needs in this particular situation. How they formulate and direct an information inquiry is consequential on their interactions. There are different methods participants use to seek information. Some information inquires are successfully answered and some are not. Maybe there are certain features that make an information inquiry better than another. How can we build an environment that better supports participants' information practices? This study demonstrates the potential of understanding an online community from analyzing their information behavior. The findings have implications on how to design and support such a math discourse community.

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