Information as a Social Achievement: Collaborative Information Behavior in CSCL

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Abstract. In computer-supported collaborative learning (CSCL) environments, learners in problem solving contexts constantly engage in information seeking, information sharing, and information use. However, these activities have not been well investigated in CSCL research. We have studied information behavior of small groups of middle school students engaged in online math problem solving. More specifically, we examined how participants negotiate and co-construct their information needs, how they seek information, and how they make sense of discovered information and use it for their task at hand. We argue that for learners in a CSCL environment, information is essentially a social achievement that emerges through the interactions of the group. Information only becomes *information* for participants when it is interactionally constructed to be meaningful and intelligible in their local situation. Analyzing learners' information behavior from such an interactional perspective can help us understand their *practices* of doing collaboration and learning. This has significant implications for designing CSCL environments and information resources to support small groups' information behavior and collaborative learning.

Keywords: CSCL, information behavior, information needs, meaning making, problem solving

INTRODUCTION

CSCL has always been concerned with how to bring people together with computer technology and to help them learn (Stahl, Koschmann, & Suthers, 2006). Yet, learning has been a contentious concept on which researchers tend to have different definitions. Researchers have attempted to identify or measure learning in various ways, corresponding to each definition, such as by comparing pre-test and post-test results, measuring the success of learner solving similar problems, soliciting individuals' own accounts of their learning experiences, and so on. The difficulty in defining learning originates from the potential risk of choosing a single definition that is too narrow or too broad, either of which can be detrimental to the production of research work in the field. When we talk about learning in our daily conversation, we may not necessarily be using one single specific criterion for defining what learning is. Learning takes place everywhere, in various contexts, and in various forms. We usually are able to *recognize* learning when it happens. Koschmann et al (2005) argue for the study of "how participants … actually go about *doing* learning" (emphasis in original) and examination of "member's methods" (Garfinkel, 1967). Precisely because of the need for an "operational definition" of learning, intersubjective meaning making (Suthers, 2006) has been put on the agenda for the CSCL research community.

So what constitute "practices" that people do in their meaning making which may lead to learning? How do we recognize these "practices" and identify the methods people use to accomplish them? In this paper, we argue that the activities participants do related to information — constructing information needs and making sense of informational resources — are essential components of the *practices* of their meaning making and learning, and thus need close examination and understanding. People have always interacted with information resources to learn. We experience intentional learning in schools, libraries, and other contexts. We also are engaged in a constant process of unintentional or informal learning in our everyday life in order to make sense of what is around us, to solve a task or a problem, to make decision, and so forth. Sense-making as defined by Dervin (1983b) as communicative behavior that all humans do in their everyday experiences is considered to have information seeking, processing, creating, and using as its central activities. Accordingly, viewing practices of doing learning through the lens of information behavior assumes an important position in our endeavor of understanding learning as activities.

At the previous CSCL conference in 2005, there were discussions on what is the central phenomenon of the interest of the research community. "*Intersubjective meaning making*" was proposed as a research agenda for the field (Suthers, 2006). In his keynote talk at CSCL 2002, Koschmann (2002) defined the central concern of the CSCL field as "meaning and practices of meaning making in the context of joint activity and the ways in which these practices are mediated through designed artifacts". Suthers has elaborated on this definition and proposed as follows:

> "The technology side of the CSCL agenda should focus on the design and study of *fundamentally social technologies* that are *informed by the affordances and limitations of those technologies for mediating intersubjective meaning making*." (Suthers, 2006) (emphasis in original)

People interact with information resources in various ways to learn. Those information resources can be from anything in natural environment to designed artifacts, can be our personal experiences represented in certain forms, or can be people around us who we communicate with. Among those, at least two big resources are of direct concern in designing CSCL environments and support: people and designed artifacts. Digital libraries as one example of online information resource have been recognized as having the potential of supporting learning (Kuhlthau, 1997; Neuman, 1997), be it for individuals or collaborative collectives. Every online digital information resource has its particular affordances and constraints; how it is organized and designed has direct impact on its accessibility and use by its users. How do we know in which way the information resource should be organized to be in accord with the learner's practices of using it? And how should these resources be designed to support collaboration among learners, which is one of the central concerns of the CSCL community? We have seen many efforts of information science researchers to define the role of digital libraries (which has a broad sense as any online digital information resource collections). Some agreement seems to have been reached to consider a digital library as a learning environment that supports social interactions (Ackerman, 1994; Twidale, 1997). Various efforts have been conducted in CSCL on researching design issues of CSCL environments to support effective learning from a wide range of perspectives. Yet, there seems to be a disconnect between these two lines of inquiry, and we feel a dialogue between the two should be carried out in order to design an integrated learning environment where learners can collaborate and their information behavior can also be augmented.

In our study reported in this paper, we examine information behavior of small groups of middle school kids engaged in math problem solving in different CSCL environments, which we call "collaborative information behavior". Through the lenses of information behavior and CSCL, we analyzed practices of small groups of collaborative participants in the environments on a micro level. During their problem-solving process, participants actively negotiate and construct their information needs by identifying what is known and what they need to know. They apply different methods and turn to various resources to find the "information" to meet their identified needs. They negotiate and construct the meaning of the discovered informational resources. Only through such social negotiation the information becomes meaningful and intelligible, that is, real "*information*" for them for their local problem situation. Information is not an object with fixed boundary but rather a social achievement of the group interaction. This *interactional* analytical point of view of seeing information has significance in helping us understand participants' practices and therefore can shed light on designs of sociable CSCL environments (Kirschner & Kreijins, 2005) to support their learning activities.

INFORMATION BEHAVIOR AND CSCL

CSCL researchers' interest in studying information behavior originated ever since the field first came into establishment around a decade ago. At the 1995 conference in Bloomington, Twidale and his colleagues (Twidale et al, 1995) reported the observations made of situated collaboration in a physical library, which informed the development of a system called Ariadne that supports collaborative browsing and other collaborative learning activities. The role of collaborative learning during information searching has been examined in the study. Guzdial (1997) brought in the perspective of information ecology to examine collaborations in CSCL environments, which describes the flow of information and the use of information, in other words, who writes notes, who reads, how many and when?

Information sharing has been a topic that has caught much attention of the field, which probably could be attributed to its intimate bond with collaboration. Many works in CSCL are built on the metaphor of "common ground" and the work of "grounding" in the contribution theory proposed by Clark (Clark & Brennan, 1991). Its focus is on sharing information through group interactions. Some researchers believe that "going from unshared to shared information" is the "gist" of cooperative learning, where individuals add knowledge to the "common ground" (Pfister, 2005). Researchers have analyzed community-based activities in CSCL setting using social network analysis (Cho et al., 2002) and examined how social influences affected information sharing within a learning community.

In the pedagogy known as Problem-Based Learning (PBL), students are encouraged to recognize and articulate what they know and what they do not know (Barrows, 1988). They examine the given materials of the problem to determine what information is available and what they still need to know and to learn to solve the problem, where they identify the "learning issues (LIs)" (Evensen & Hmelo, 2000). The students then research the learning issues and reconvene to share what they have learned. Their problem is reconstructed using the newly discovered information. They also evaluate their own information as well as that of the others and critique their resources in the reflection phase. As identified by Bereiter and Scardamalia (2000), one of the notable similarities between collaborative knowledge building (Scardamalia & Bereiter, 1994) and PBL as practiced in medical schools is that "an important part of work on a problem is identifying what needs to be found out in order to advance".

Stahl & Koschmann (1998) have also examined the process of collaborative information seeking a group of medical students engages in within a PBL context. There are successive phases students go through in the process of producing learning issues (LIs), namely recognition, researching, reporting, and reflection. The collaborative problem-solving process is an instantiation of collaborative information seeking. The vision of what roles technology might play in supporting PBL suggested by their research has significance in providing insights to design CSCL environments to support collaborative information behavior that takes place within the process. The suggestions include highly-interactive real-time environment, digital shared whiteboard, information sharing software, and more structured shared representation tools, etc.

INFORMATION AS A SOCIAL ACHIEVEMENT

Human information behavior has remained one of the central topics within the field of information science. Though various definitions of information behavior have been given, one that seems to be commonly accepted defines it as "the totality of human behavior in relation to sources and channels of information, including both active and passive information seeking, and information use" (Wilson, 2000, p. 49). For decades, information science researchers have been studying "how people need, seek, give, and use information in different contexts" (Pettigrew 2001). Quite a number of theories, methodologies, and frameworks have been put forward as results of these endeavors, which are drawn from different disciplines encompassing library and information science, cognitive science, psychology, social science, communication, philosophy, and so on (Fisher et al, 2005).

Studies in information science have encompassed different meta-theoretical positions from seeing information as the direct transfer of messages between senders and receivers (Shannon & Weaver, 1940) to cognitive constructivism, where information is being considered as socially constructed and thus situated in user's context (Dervin, 1983; De Mey, 1982; Ingwersen, 1999). Conventional information science studies have primarily had a cognitive philosophical base, upon which individuals as information users are seen to have specific states of knowledge and they interact with information resources. Researchers like Dervin (1983), Belkin (1980) and de Mey (1982) suggested more context-sensitive interpretations of the cognitive viewpoint. With emphasis on situational relevance, cognitive constructivism moved from the individual toward a more socio-cognitive position (Ingwersen, 1999, pp 4-16). More recently, some researchers have started to argue that information processes should be seen as embedded in social, organizational and professional contexts. They shift attention from individual knowledge structures to "knowledge-producing, knowledge-sharing and knowledge-consuming communities" (Jacob and Shaw, 1998, p142). Such view point is influenced by Vygotsky's social constructivist theory and Leontiev's activity theory. As Cornelius (1996, p. 18) put it:

> Anyone […] who is using information is participating in a practice, is a part of social life. His or her actions should be understood as social actions, and the significance or meaning which any participant in a practice imparts to one of the objects of that practice (which could be a piece of information) is a socially constructed one.

Researchers also have started to consider that information and information processes should be approached from the perspective of the social discovery and construction of knowledge, meanings and representations (Hjørland, 1992c).

Distinguished from the cognitive viewpoint of seeing information as an object with fixed boundaries, constructionism's primary emphasis is not on mental but on linguistic process (Tuominen, Talja, & Savolainen, 2005). It sees language as constitutive for the construction of self and the formation of meanings. People organize and produce social realities together by using language. The late language philosophy of Wittgenstein argues for the practical and fundamentally social nature of discursive practices. Constructionist approaches in information science consider information, information systems, information needs and others are produced within discourses, i.e. linguistic and conversational constructs (Talja, 1997; Tuominen and Savolainen, 1997). These studies show how information practices – often analyzed from a behavioral perspective – look different and reveal new sides when looked at as part of the social negotiation of meanings. In our study of small group collaborative information behavior situated in a CSCL setting, we take up this constructionist viewpoint and analyze the practices of participants identifying their information needs, finding resources, and constructing meaning of informational resource, during which information emerges as a meaningful product of such social achievement.

Harold Garfinkel (1967) founded *ethnomethodology*. This branch of sociology studies the routine ways by which actions, including talk-in-interaction, are performed to constitute the intersubjective reality of social life.

Harvey Sacks (1974), who worked closely with Garfinkel, developed a similar methodological approach for the close analysis of ordinary talk-n-interaction and called it *conversation analysis*. We have applied an ethnomethodologically informed approach that combines aspects of conversation analysis and ethnomethodolgy to analyze information practices of participants within a CSCL setting. This approach stresses close examination of interactional data in data sessions, to identify and describe the observable methods participants use to make sense of their interactions for themselves and each other. Data sessions are perspicuous analytical environments in which the data are examined by numerous analysts and noticings and findings are discussed.

We have observed the process by which small groups of middle school kids engage in solving a mathematical problem collaboratively in virtual environments. In a research project called the Virtual Math Teams (VMT)[1], we invite students to participate in about an hour-long sessions where they work with a few others on a math problem, which is designed by the Math Forum[2] staff and VMT researchers to encourage mathematical thinking. We believe kids learn more effectively by talking about math and working in groups. Usually there will be one facilitator present to get the group started but it is up to the group to figure out the math. In this study reported here, we particularly focused on examining how students identify and construct their information needs collaboratively, how they go about finding the information, and how informational artifacts are produced and recognized as meaningful and useful information for them. *Information is not given, but is a kind of status accorded various situated, locally designed and produced artifacts. This status is not a feature of the artifact but is produced as an interactional achievement*. For example, in a conversation carried out among a group of people, how do we know whether a question asked by one person is an inquiry for information? The status of the query depends on the design of the query, the response and the subsequent work done by the interrogator and other respondents to retrospectively assess the status of the query. If one person addresses the question "what time is it?" to another, she may be asking for information, or what she really means is "shall we head off to pick up our pizza?" We can see whether her question is an inquiry for time or a request for action by looking at the circumstances under which the query was produced, the actual design of the query and the kind of answer that is given: "It's a quarter past 7" or "Oh, yeah, I think it's time for us to go now…" Actions project proper subsequent actions and performed subsequent actions alter the sense and propriety of the preceding actions. The status of the query is interactionally determined over the sequence of action in which its sense is being worked out.

In VMT sessions where students are interacting through the online environment, they collaborate virtually using the resources made available to them in the system, which include the chat system, or in the later version of *VMT Chat* environment a shared whiteboard and other functionalities such as referencing tools. What they interact with is not people who they can physically see, but only the messages posted by participants in the same environment and whatever is made visible and available to them through the system. The record of the conversations along with other activities are preserved, which can be accessed by participants and researchers later on when they come back to the chat room. These activities can also be reconstructed by a replay tool developed for researchers to see the temporality and sequentiality of the actions as well as how they are coordinated in a real time manner. In this way, what is made visible to participants engaged in the interactions is also visible to the researchers to a large extent. Of course there may be some contextual information that is available to participants at the situation but not necessarily visible to researchers even though the interactions are reconstructed to some degree. Nevertheless, the extent that the group interactions are exposed to examination poses unique opportunities for us to look into the issues such as the evolving process of information needs and use of information from an interactional perspective, which are otherwise relatively less accessible thus difficult to study if treated as psychological phenomena.

Stahl — in his recently proposed theory of *Group Cognition* (Stahl, 2006b) — argues that the small group can be the most fruitful unit of analysis for studying learning and meaning-making. Our study has taken the small group as the unit of analysis and examined the phenomenon of information behavior in collaborative learning at a micro-level.

CONSTRUCTION OF INFORMATION NEEDS

When people realize there is a knowledge deficiency, that is, their current knowledge is not adequate to solve an anomaly in the state of knowledge (Belkin, 1980), to solve a problem or bridge a gap in understanding (Dervin, 1983a), they are in need of certain information. Most information retrieval (IR) systems are operated on a "best-match" principle, which returns the texts that are considered best matches to what is expressed and specified by the user as a representation of information needs. However, such underlying assumption that what a user specifies as a query is an ideal representation of his/her information needs is questionable and unwarranted. This component of an IR system has been questioned by many researchers and thus brought up another central issue

[1] www.mathforum.org/vmt

[2] www.mathforum.org

of document relevance. Belkin proposed his famous hypothesis of the *anomalous states of knowledge* (ASK) to characterize that information needs are not in principle precisely specifiable (Belkin, 1980). An information need arises from a recognized anomaly in the user's state of knowledge concerning a certain situation and in general the user is unable to articulate and specify what is needed to resolve the anomaly. Belkin believes that it is possible to elicit problem statements from users and the representation of information needs can be derived from carefully designing information systems (Belkin, 1990). Unfortunately more than decades after this proposition, information retrieval systems still have not taken up the suggestions. One obstacle of implementing it in a real system may lie in the difficulty of testing such a hypothesis and to derive a set of operational guidelines for system design. Such difficulty may be attributed to the underlying cognitive viewpoint, which assumes that states of knowledge are something residing in an individual's head while it is hard, if not impossible, to get into a person's mind and find out what may be going on. The following excerpt and analysis of it is an example demonstrating how participants in a small collaborative group negotiate and construct their information needs through the group interactions.

The following six and a half minute long except is from a VMT chat session during which three participants (REA, PIN, MCP) are working on a geometry problem as presented in figure 1 through AOL chat program.

Finding CE - posted February 16, 2004

Given the following situation:

- Side AB of triangle ABC has a length of 8 inches.
- Line DEF is drawn parallel to AB so that D is on segment AC and E is on segment BC.
- Line AE extended bisects angle FEC.
- DE has a length of 5 inches.

What's the length of CE?

Figure 1. Problem: Finding CE

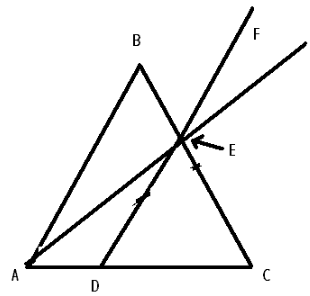

Figure 2. The drawing

It is about half way through a one hour and twenty minutes session. There is a moderator in the chat room who got them started by first greeting them, presenting the problem, and explaining the task for them is to share their ideas and collaborate on solving the problem. They are also asked to make sure everyone understands if they think the problem gets solved. Before the conversation gets to this point, REA and PIN have already engaged in active discussion on solving the problem. One of them created a picture as shown in Figure 2 and sent to the moderator. It was made available to the group through a website, which they have been referring to in this excerpt of their interaction. There was a third participant (GOR) who was participating peripherally and dropped out of the discussion before MCP joined the group. As requested by the moderator, they explained to MCP what they have got so far of their progress on solving the problem.

Table 1: An example of negotiation of information

Line #	*Handle*	*Posting*	*Time*	*Delay*
120	REA	Are u there PIN	8:48:08	0:00:17
121	PIN	ya im here	8:48:29	0:00:21
122	REA	checking	8:48:37	0:00:08
123	REA	u stuck cause i am:-(	8:49:07	0:00:30
124	PIN	well angle CED is congruent to angle B	8:49:56	0:00:49
125	PIN	if that helps	8:50:06	0:00:10
126	REA	It helps	8:50:48	0:00:42
127	REA	but i already estlabished that	8:51:15	0:00:27
128	PIN	im stuck	8:51:36	0:00:21
129	MCP	What's known?	8:51:42	0:00:06
130	MCP	BE:EC = 3:5, right?	8:52:05	0:00:23
131	REA	how did you get that	8:52:42	0:00:37
132	PIN	how did u get that	8:52:43	0:00:01
133	PIN	lol	8:52:46	0:00:03
134	MCP	Tri ABC similar to DEC	8:53:10	0:00:24
135	PIN	ya we got that	8:53:19	0:00:09

136	MCP	AB:DE = 8:5, right?	8:53:30	0:00:11
137	REA	We know that	8:53:33	0:00:03
138	PIN	ya	8:53:35	0:00:02
139	MCP	So BC:EC=8:5	8:53:51	0:00:16
140	REA	ya	8:54:11	0:00:20
141	MCP	That 8 breaks down 3 for BE, 5 for EC	8:54:23	0:00:12
142	REA	We might have to use law of sines	8:54:38	0:00:15

Analysis

REA's posting at line 123 is seen as a question directed to PIN asking about PIN's status on working out the problem: "(are) *you stuck* (?)". This is addressed particularly to PIN because this immediately follows a previous question by REA whether PIN is still there. Line 123 also displays REA's own position as "*I am* (stuck)". It can be also read by its addressee as not only an inquiry to his/her status into the problem solving, but also a request for information that could possibly help him getting "unstuck". This is precisely how it is taken up by PIN (after 49 seconds of silence in the conversation): PIN responds with providing some information that he possibly discovers from the problem description ("*angle CED is congruent to angle B*"). PIN starts with "well", which indicates his taking up REA's inquiry, possibly with certain hesitance on positioning himself to offering something to satisfy the request. This offering of informational resource is followed by "*if that helps*", calling for work of assessment of its usefulness in terms of solving the problem. REA ratifies the usefulness of the information but states it is not new at this point ("*but I already established that*"). REA's evaluation of what PIN brings in sets the situation into the following: a request for information is made; an attempt of providing the information is assessed as "useful" but not new; therefore the earlier request is still open but revised as a request for something new, that is, something that has not been "established" yet. PIN articulates he cannot be any help to take up the request at this point. This situation opens up an opportunity for other members to bring in any new, potentially "useful" information.

Right at this moment, MCP joins this line of conversation by asking a question "What's known?" One of the features of this query is that it is calling for recipients to consider a set of cognitive resources that can be shared. Knowledge, in commonsense usage, is exchangeable, allocatable, distributed, etc. Understanding, on the other hand, is usually treated as a cognitive resource that can be demonstrated but cannot be exchanged. By asking about what is known, MCP is opening up the possibility of exchange of knowledge. Looking at what follows (line 130), this can be read as a rhetorical question, which summarizes the situation as "we need to find out what's known". Whether it is or not, it serves to preface what will follow as information action, organizing action in relation to others and to available resources in ways that provide for subsequent postings to be seen as informative. The question can also be seen as directed to the group and calls for collaboration and brainstorming on finding out *what's known*.

MCP takes over the call himself/herself by proposing a math proportional equation as a candidate of "what's known". This proposition is phrased as a question (line 130 "..., right?") to solicit either assessment or consensus from the group. We identify such as a math proposal, which usually falls the pattern of having subsequent response(s) that together form a *math proposal adjacency pair* (Stahl, 2006d).

This proposal is responded by each of two participants. Question phrased in almost exactly the same way is expressed by REA and PIN respectively at almost the same time (1 second difference between the two postings as shown in the time stamps). The question is clearly directed to MCP and to be read as an inquiry for further information, that is, a request for MCP to produce some elaboration or account for what he just provided as "known" fact. We see that three co-present participants displayed different levels of understanding on what is known at this point. This discrepancy needs to be resolved to bring the group into sync in order for them to proceed with collaborative problem solving, that is to say, the situation calls for the need of "grounding" work (Clarke & Brennan, 1991) to build a common ground for their subsequent interactions. The work of grounding is essentially sharing information through interactions among the participants. In this excerpt, MCP is called upon to elaborate on his offering and share what he knows with the rest of the group. This is what we will see shortly in the following interactional moves. We will also see that "information sharing" here is not simply transferring a piece of information as a bounded object. Rather, participants do the work of building understanding of the *information* in their situated locus. It is the work they do that makes a potential informative artifact meaningful and intelligible for them.

In the rest of this excerpt, MCP takes up this request and tries to present to the group how that "known" fact is derived by what is given in the problem step by step. This expository work (Zemel, Xhafa, & Stahl, 2005) of MCP as an effort of producing an account of the information is led by an organized way of presenting base facts and what is derived from those, each step is aligned with agreement or acknowledgement from the group members. In line 141, by concluding "*That 8 breaks down 3 for BE, 5 for EC*", MCP completes this process of *presenting a proof as the work of information sharing and grounding*.

The last line of this excerpt comes 15 seconds after the preceding posting, which is a relatively significant and noticeable gap in a live chat (which we have witnessed in some of the previous postings too of course). MCP's last posting as part of the offered explanation doesn't get response here. Maybe what is being conveyed in the posting is obvious enough for the participants so it is not necessary to make any acknowledgement, which on the other hand could also be implicit acknowledgement or acceptance. Maybe the way this line is composed is not designed to call for a response. The fact that this thread of expository work stops here marks the conclusion of the work of producing an account of the "known" fact "BE:EC = 3:5" previously presumed by one member and at the same time, the work of making meaning of this account by rest of the members. This also signals the transition between threads of conversation and opens the interactional space up possibly for a new incoming proposal. REA makes a proposal that suggests the possibility of using "law of sines" as a strategy to progress on solving the problem, which we will be discussing in another short excerpt that immediately follows this one. Now the group presumably will be oriented to this new information resource brought in by REA, which is still situated under the bigger theme of their interest of discovering or producing new information to get "unstuck" and move towards solving the problem at hand.

Table 2: group as an information ground

142	REA	We might have to use law of sines	8:54:38	0:00:15
143	PIN	havent learned that yet	8:54:50	0:00:12
144	PIN	whats it say	8:55:04	0:00:14
145	MCP	Sine A / a = Sine B / b = Sine C / c	8:55:15	0:00:11
146	MCP	in any triangle	8:55:23	0:00:08
147	REA	right	8:55:28	0:00:05
148	REA	it is like A/sin a= B/sin b= C/sin c	8:55:55	0:00:27

The proposal by REA (line 142) is carefully phrased as "we might have to", which indicates the author is putting this out in a defeasible position for the group to scrutinize. By stating s/he hasn't learned *that* yet (where *that* unambiguously refers to the *law of sines* in the closest posting), PIN positions himself as an inquirer soliciting more information on this. Considering MCP's response offering the equations of law of sines that is relatively complex and requires time to type in but comes in 11 seconds after PIN's request, PIN's positioning statement at line 143 may have been recognized as an inquiry for further information before the actual inquiry in the form of question actually gets posted. The equation/definition offered by MCP is reified by REA: "*right*". What immediately follows is rather interesting: it starts with "it is like" which gives readers expectation of what is coming after, likely further explanation or elaboration of some sort while what we see here is a seemly very similar format of the equation (*A/sin a= B/sin b= C/sin c*). With "it is like" being said, this version of equation is supposed to be in agreement with what was posted earlier. In geometry convention, an upper case letter like "A" is usually used for referring to an angle whereas a lower case letter like "a" for the opposite side of angle A. This is the convention to which MCP's description of law of sines conforms. In REA's equation, the uses of upper case and lower case letters are switched, which of course is acceptable in geometry providing you define them first. If the law of sines were perceived by the participants as relevant thus useful for their problem situation, this difference in two representations would have influenced the subsequent interactions. And in this case we would have the chance to see what REA's posting in line 148 is designed to be read. However, this line of inquiry stopped at this point and they didn't make it much further.

Table 3: difficulty of using information resource into problem situation

221	PIN	MCP got any ideas?	9:09:34	0:00:10
222	MCP	Still just the proportions I gave before.	9:09:55	0:00:21
223	REA	I got that proportional statement and the law of sines	9:10:04	0:00:09
224	REA	but i can't put it together	9:10:16	0:00:12
225	MCP	4 congruent angles	9:10:21	0:00:05
226	PIN	its something with the bisector	9:10:30	0:00:09
227	MCP	Yeah, that's where the 4 come from	9:10:49	0:00:19

As we see in the short excerpt above, participants are still making efforts trying to figure out what they could use what is known so far to move further on solving the problem. Up to this point, which is about 14 minutes after the discussion from the last excerpt, nothing new has been discovered. REA articulates the difficulty s/he has been encountering associating two pieces of informational resources to produce a solution (line 223, 224). MCP and PIN seem to be actively pursuing the inquiry: MCP adds one more known fact - “4 congruent angles” - onto REA’s two pieces whereas PIN is trying to remind the group about the “bisector”, which may be a point to break through.

Discussion

Information needs may arise in a variety of circumstances. One such circumstance is when a group must solve a problem, as in the case we considered above. There, participants realize there is deficiency of what they know and what they need to know in order to solve the problem. But what they need to know may not be clear at the beginning stage and they have difficulty specifying and articulating. We have observed participants use certain methods to resolve such anomaly in their state of knowledge. One of the most commonly used methods is posing a question to the group that starts the process of identifying what is known. The question could be an information inquiry that specifically requests for information. Or it could be phrased in a way that is asking for help. Participants do the work of recognizing such information inquiries and taking them up by providing information that is considered to be relevant to addressing the inquiry. In the previous except (Table 1) we have just looked at, one participant poses a question that at first glance looks like an inquiry of another participant’s status as in the progress on the problem solving (line 123 REA: u stuck cause i am:-( ) But the question is taken up by its addressee PIN as an inquiry for information on the problem: PIN provides the known information he thinks might be helpful to REA which indicates that he sees PIN’s question not as only checking for his status but a request for help, which can be addressed by providing information.

Information needs start with an anomalous state and evolve in and through the interactions of participants. They are changed and shaped with new information being introduced (Bates, 1979a; 1989). The meaning participants construct and attribute to the introduced information changes the current state of knowledge, which therein shapes what still remains to be known. On the other hand, what is known changes their understanding of the problem. The problem and information needs shape each other in a dynamic way. Information in such a process is never fixed but always negotiated and constructed as an interactional accomplishment of the process. For example, we have seen that MCP treats “BE:EC = 3:5” as something “known” and asks for confirmation. This information does not become meaningful and useful for the other participants until they find meaning in it thanks to MCP’s explanation work.

Participants apply strategies to move forward the collaboration on this matter of constructing information needs. By asking “what’s known?”, MCP proposes finding out what’s known as a relevant and useful thing to pursue. This is posed as a question, be it rhetoric or addressed to the group, it does the work of bringing the proposal to conjoint consideration.

There is grounding work (Clark & Brennan, 1991; Roschelle, 1996) participants do in such a negotiation process, sharing information to build a common ground for the group’s collaboration. The work of grounding is intertwined with the meaning making of the information, that is, the outcome of such effort is a product of meaningful information as an accomplishment of such a process. In this particular case, such process is exemplified as MCP’s doing expository work while two other participants are doing the work of meaning making.

The shared space where participants are engaged in collaborative problem solving is an information ground where they seek and share information. Built upon Tuominen and Savolainen’s (1997) social constructionist approach, Pettigrew defines information grounds as synergistic “environment[s] temporarily created when people come together for a singular purpose but from whose behavior emerges a social atmosphere that fosters the spontaneous and serendipitous sharing of information” (Pettigrew, 1999, p. 811). We have observed participants in such an environment actively engaged in finding information. The group they are working with is always the most important resource for them, where they ask for help, request information, pose their proposal for assessment, and so on. Participants use external online resources too to satisfy their information needs. We have seen the use of Google, online tools, the Math Forum digital libraries, etc. by participants in search for certain information. They bring in what they discovered to share with others and co-construct the meaning of it.

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