Technology Affordances for Intersubjective Learning: A Thematic Agenda for CSCL

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Abstract. The study of technology affordances for intersubjective learning is proposed as the thematic agenda for CSCL. Work that does not consider intrinsically interactional mechanisms of learning or does not study affordances specific to technology support is still valuable but is not considered central to the CSCL agenda. A fusion of experimental, ethnographic and design methodologies is also proposed. A working definition of intersubjective learning as joint accretion of interpretations on a dynamically evolving context is provided, along with an outline for analysis under this definition.

Keywords: CSCL research agenda, interactional practices, representational affordances

INTRODUCTION

The primary purpose of this paper is to propose a thematic agenda for CSCL for the next 10 years (or perhaps less if we make great progress). Koschmann (2002) has characterized CSCL as the study of "practices of meaning-making in the context of joint activity and the ways in which these practices are mediated through designed artifacts." I accept but elaborate on this definition, and organize my presentation accordingly. The proposal is motivated by an overview of work in CSCL in which I characterize various concepts of "collaborative learning" in terms of their underlying epistemologies, and the different forms of "computer support" explored by practitioners for these notions of learning. I then present my view of where the "soul" of CSCL lies within the diversity of this "body" of work. My assessment of the state of the field is based on familiarity with recent CSCL conference proceedings and book series, although the brevity of this paper prohibits full citation of the relevant literature. Therefore, my presentation is analytic rather than empirical, making a case for what *should* be the thematic focus of CSCL based on identification of those problems in the nexus of computer mediation and collaborative learning that are our special concern.

EPISTEMOLOGIES FOR COLLABORATIVE LEARNING

Any complete CSCL research agenda will be based on assumptions, implicit or explicit, concerning the question of what it means to learn in collaborative settings. If learning means gaining new knowledge, then this is an epistemological question.

A *knowledge-communication* epistemology (Wenger, 1987) continues to be common in the CSCL literature (e.g., Bromme, Hesse & Spada, in press). In this view, knowledge is acquired by communication from one agent (typically the teacher or computer) to another agent (typically the learner), including learning by being told, coached, tutored, or modeled (learning by observation). Under this epistemology, CSCL research examines how to more effectively encode or present knowledge in some medium, or how to ensure that a communication medium is rich enough to support the required communication between teacher and learner. However, this model does not address aspects of learning that are specific to collaboration. Many authors in CSCL profess allegiance to an epistemology that is both more constructivist and more interactional.

A *constructivist* epistemology (Piaget, 1976; von Glaserfeld, 1995) emphasizes the agency of the learner (rather than that of a teacher) in the learning process. Learning can only happen through the learners' efforts to make sense of the world, although a mentor might arrange for the learner to have rich yet problematic experiences in order to accelerate the change process. Computer support for such experiences includes simulations and "microworlds" (Rieber, 2004). CSCL researchers rarely take this view to its solipsistic extreme. Instead, constructivism takes the form of "collaborative knowledge construction" (Stahl, 2000), implying an interactional constructivist epistemology.

An *interactional* epistemology suggests that we examine how interactions between people lead to learning. Many CSCL authors (e.g., Baker, Hansen, Joiner & Traum. 1999; Rummel & Spada, in press; van Der Pol, Admiraal & Simons, 2003) build their interactionalism on the concept of common ground from Clark's

contribution theory (Clark & Brennan, 1991). Pfister (in press) proposes that adding knowledge to common ground "is the gist of cooperative learning: going from unshared to shared information." Contribution theory has its limitations (to be discussed later). So also does this conception of learning in groups. In focusing on the sharing of information (presumably that was formerly held by a subset of the participants), it does not encompass learning accomplished through *joint construction of interpretations*. A more radically interactional epistemology, which I shall call *intersubjective learning*, goes beyond an information sharing conception of collaborative learning in two ways: it can be about sharing *interpretations* as well as information, and these interpretations can be *jointly created* through interaction, in addition to being formed by individuals before they are offered to the group. It claims that not only is learning accomplished through the interactions of the participants, but also *consists of* those interactions (Koschmann et al., in press).

Different socially contextualized models of learning vary in the extent to which they incorporate an intrinsically interactional or intersubjective epistemology. One can maintain that learning remains fundamentally a process within individual minds, yet this process can be enhanced through contacts with other minds. For example, cognitive dissonance theory (Festinger, 1957) and socio-cognitive conflict theory (Doise & Mungy, 1984) can be read this way. Learning can be viewed as a process of becoming a member of a community by acquiring that community's practices and world-view through "legitimate peripheral participation" (Lave & Wenger, 1991), with the possibility but not the necessity that this participation changes the community's practices. Learning can also be seen as the internalization of social processes as cognitive processes (Vygotsky, 1978). In addition to knowledge construction, the literature also presents us with *knowledge building*, which would seem to be nearly identical in meaning but is intended in a different sense better captured by Scardamalia and Bereiter's (1991) original phrase "intentional learning." The essential difference between knowledge building and other forms of learning (constructivist or otherwise) is that knowledge builders are deliberately and through their own collective agency pushing the boundaries of their knowledge (i.e., are learning intentionally).

For the purposes of this paper, I will use *collaborative learning* to encompass all socially contextualized forms of learning. The other phrases are layered in the following manner: *knowledge construction* recognizes that individuals create their world view rather than just receiving it preformed from others; *collaborative knowledge construction* more specifically locates this meaning-making in a group context; *intersubjective learning* further specifies that the process of meaning-making is itself constituted of social interactions; and *knowledge building* requires that this group-based meaning-making is being done intentionally.

CS: COMPUTER "SUPPORT" OR MEDIATION

Let us now add computers to the mix. In what ways can we bring technology to bear on the problem of supporting collaborative learning, as it is variously conceived? This section identifies three major ways in which technology can be applied to support collaborative learning: as a collaboration medium, as controller, and as resource. The prior discussion is relevant because our choice of an epistemology of collaborative learning can affect how we approach the design of computer mediation and what questions we ask in our research. For example, under a knowledge-communication model, we will think about the information technologies we are designing as communication channels, focusing on the ease with which one can move information and interpretations of that information between participants. Under an intersubjective learning model, we might design information technologies as forums within which new ideas can be discovered and evaluated. The difference is between maximizing the bandwidth between agents and designing affordances for joint knowledge construction and discovery. However, it is also possible to support collaboration without making any particular commitment to a theory of collaborative learning. I begin with this epistemologically minimalist approach.

Technology as Communication Medium

People often resort to computer-mediated communication (CMC) as a substitute for face-to-face interaction in order to make communication possible between people at different locations (synchronous distance communication) or at different times (asynchronous communication). It is not surprising that face-to-face (FTF) communication would then be taken as the standard against which CMC is evaluated (Olson & Olson, 2000). Research in this tradition tries to improve the bandwidth and multimodality of CMC technology and fine-tune its design to match the characteristics of FTF. For example, gaze and gesture are demonstrably vital cues in FTF interaction, so some researchers study how to arrange cameras such that the remote image of a person gives a more accurate indication of what they are looking or pointing at (e.g., Kato et al., 2001). Although FTF interaction has great value, we should not assume that online replication of FTF is the only or even a primary goal of CSCL, for four reasons.

First, CSCL does not necessarily replace FTF interaction. Computational artifacts can also augment spoken and gestural communication between co-present collaborators (Roschelle, 1994; Suthers & Hundhausen, 2003), and be embedded in classrooms where much of the interaction is FTF (Lingnau, Hoppe & Mannhaupt, 2003; Scardamalia & Berieter, 1991; Toth, Suthers & Lesgold, 2002).

Second, although further progress can be made, ultimately the goal of replicating FTF interaction online may not be achievable. "Distance matters" (Olson & Olson, 2000) in many subtle ways when collaborating through technology. Even with extremely high bandwidth communication in multiple modalities, advantages of spatial co-location will be difficult to replicate online, such as access to implicit contextual information, gaze and gesture as cues for identifying deictic referents, and the use of space to organize ideas and coordinate action.

Third, it may not even be desirable to merely replicate FTF interaction. As Pfister (in press) puts it "even if virtual reality is achieved ... genuine learning discourse is not supported. It is completely up to the participants ... how to structure the learning process" (Pfister, in press). Rather than leaving efficient learning up to the learners, CSCL has an obligation to design technology that supports effective collaborative learning. In order to do so, some kind of a commitment to an epistemology of effective collaborative learning is necessary.

Fourth, CSCL can explore the advantages of going "beyond being there" (Holland and Stornetta, 1992): ways in which CMC is actually *better* than FTF. An obvious example is that CMC "turns communication into substance" (Dillenbourg, in press), providing additional resources for learning. The record of communication and shared representations that are manipulated during communication provide a shared persistent information base that enables the community of collaborators to reflect and act on its own state of understanding—to reinterpret, find connections between, refine and expand information and ideas explored over time.

Research that focuses primarily on supporting communication is not at the center of CSCL in that it does not necessarily directly address issues of learning. However, nor is such research peripheral to CSCL. Indeed, understanding the unique affordances for communication and collaboration offered by technology is as foundational to CSCL as understanding learning. Much further work is needed to answer questions such as: What strategies do people use to manage collaboration via written and other artifact-mediated means? How are the affordances of various media (including information technologies) appropriated to carry out these strategies? How then can we design our CMC and CSCL environments to provide those affordances with the most natural match to required communication strategies?

Technology as Constraint

Information technology, as well as other technologies such as paper based instructional materials, is often applied to education as means to limit the options available to learners. Although it sounds negative, this is sometimes a useful strategy.

Properly applied, constraints can resolve a paradox of collaborative learning. Collaboration imposes an additional task on the learners: in addition to choosing actions within the problem domain and attending to what they are learning from those actions, they must also manage interpersonal relations and group functioning (Whitworth, Gallupe & McQueen, 2000). Learning may be reduced if less cognitive resources are dedicated to the learning task. However, if learners can help each other with different parts of the learning activity, collaboration can reduce task load and can increase learning effectiveness through activities that are more difficult to do alone, such as argumentation, explanation and reflection (Andriessen, Baker & Suthers, 2003; Slavin, 1995). To resolve this paradox, instructional technology is often designed to structure part of the collaborative learning activity, "offloading" this work onto the technology so that learners can focus their cognitive and social resources on other relevant aspects of the learning activity. The technology support can take different forms, such as full automatization of the offloaded task, constraining actions to reduce the need to make decisions and the risk of errors while executing the task, or non-mandatory guides such as coaching agents or representational guidance. Whatever form it takes, this support might be subsequently removed (the "scaffolding" "fades" in this mixed metaphor) as learners internalize the guidance it provided.

Technology constraints can also be used to enforce a learning agenda. Analysis of the learning task may reveal prerequisites and uncover difficulties that are best left for after fundamental skills are learned. Then, guidance is applied via any of the methods previously listed (automatization, interface constraints, coaches, representational guidance) to ensure that skills are acquired in an optimal order. The choice of what parts of the task are "scaffolded" and when and how "fading" occurs can be an effective use of technology to implement a learning agenda. Similarly, constraints can be used to enforce a collaboration protocol, perhaps even one based on an epistemological commitment as to what constitutes effective learning through collaboration. For example, several researchers have identified collections of conversational moves that they believe are necessary for an effective learning dialogue, and implemented these moves as mandatory sentence openers in a communication interface (Baker & Lund, 1997).

Technology as Resource

Finally, we can view technology as a resource to be drawn upon to support the process of learning collaboratively. CMC environments record communication in a persistent medium that can support reflection and interpretation, as mentioned earlier. Disciplinary representations such as models, simulations and visualizations also serve as resources for conversation. Rather than being vehicles for communicating expert

knowledge, they become objects about which learners engage in sense-making conversations (Roschelle, 1994) and can be designed to lead to productive conversation. Another example of how technology can serve as a resource for collaborative learning is technologies that foster *group awareness*. The mere awareness that others are present and will evaluate one's actions may influence one's choice of actions. Information about the attentional status of group members and their attitudes towards previously proposed ideas may influence the actions of individuals in the group. Visualizations of conflict or agreement between members may lead to further argumentation or reaching of consensus.

There is some overlap between technology as communication medium, resource for conversation, and guide. Consider shared representations such as argumentation and modeling tools. Collaborators may feel some obligation to discuss proposed or just-taken actions on shared representations with their partners. The potential for action afforded by the representational notation will influence the actions that are discussed; thus the representation biases the conversations that take place to be about those ideas motivating the afforded actions (Suthers & Hundhausen, 2003). Also, jointly constructed representations become imbued with meanings for the participants by virtue of having been produced through a process of negotiation. These representational constituents then enable easy reference to prior ideas with deictic reference (through gesture or language), or by direct manipulation (Suthers, Girardeau, & Hundhausen, 2003). The expressive and indexical affordances of a representational communication medium will affect its value as a resource through these processes.

AGENDA: TECHNOLOGY AFFORDANCES FOR INTERSUBJECTIVE LEARNING

What To Study?

The Interactional Accomplishment of Intersubjective Learning in Small Groups

Koschmann's definition of CSCL as being concerned with the "practices of meaning-making in the context of joint activity" can be understood under many of the epistemologies previously discussed. Like the Hindu parable of blind men feeling an elephant and each describing it differently, all are describing some aspect of the truth. However, the question we face is how to most productively focus our research efforts. We may already know how to swat the elephant in the rear and get it to move forward, but do we know how to climb on top and make use of the trunk?

The aspect of the collaborative learning elephant that is least understood is what I have been calling *intersubjective learning*. As previously discussed, this is learning that is not only accomplished interactionally but is also *constituted of* the interactions between participants. Koschmann et al. (in press) argue for the study of "member's methods" of meaning making: "how participants in such [instructional] settings actually go about *doing* learning" (emphasis in original). In addition to understanding how the cognitive processes of participants are influenced by social interaction, we need to understand how learning events themselves—for example, the identification of a need for change, the working through of alternatives, and the tentative acceptance of a new interpretation—take place in the interactions between participants.

I claim that intersubjective learning is the aspect least understand in CSCL because it is more difficult to find research publications within CSCL that directly address this epistemology. The study of joint meaning-making is surprisingly not presently prominent as a topic of study in our field. Even where process data (rather than outcome data) is examined in detail, the analysis is typically undertaken according to coding categories that count features that are essentially proxies for the phenomenon of interest rather than seeking to uncover those phenomena directly (e.g., Nurmela, Palonen, Lehtinen & Hakkarainen, 2003; Rummell & Spada, in press). I am also guilty as charged (e.g., Suthers & Hundhausen, 2003).

A few studies published in the CSCL literature have addressed this problem directly, for example, Koschmann et al. (2003), Koschmann et al. (in press), Roschelle (1994) and Stahl (in press). Koschmann's work has generally focused on participants' methods of *problematization*; identifying a situation as problematic and requiring further analysis, possibly leading to a change of conception. This research is only the beginning. We also need to identify methods for resolving the problematized issue. I have speculated that these will include methods for exploring interpretations (argumentation) and negotiating an interpretation that is sufficient to meet the task demands (achieving a working consensus).

Stahl (in press) argues that small groups are the most fruitful unit of study, for two reasons. Most simply, small groups are where members' methods for intersubjective learning can be observed. Groups of several members allow the full range of social interactions to play out, but are not too large for participants and researchers alike to keep track of what is going on. More interestingly, small groups lie at the boundary of and mediate between individuals and a community. The knowledge building that takes place within small groups becomes "internalized by their members as individual learning and externalized in their communities as certifiable knowledge" (Stahl, in press).

The study of the interactional accomplishment of intersubjective learning involves interesting questions that are among the most challenging facing any social-behavioral science, and even touches upon our nature as conscious beings. Do cognitive phenomena exist transpersonally? How is it possible for learning as a cognitive

function to be distributed across people and artifacts? How can we understand knowledge as accomplished practice rather than as a substance or even predisposition? Yet I would not leave individual learning behind. In support of this research agenda, cognitivists can ask: What is the relationship of the change process we call "individual learning" to that individual's participation in socially accomplished learning?

Technology Affordances for Intersubjective Learning

Let us consider the appropriate role of "computer support." The second half of Koschmann's definition of the domain of CSCL is "the ways in which these practices [meaning-making in the context of joint activity] are mediated through designed artifacts." Computer support for intersubjective meaning making is what makes our field unique. Other fields have investigated computer support for collaboration, intersubjective meaning making, and computer support for other models of learning such as knowledge-communication and constructivism. But what form of support is most fruitful for our research?

I propose that technology side of the CSCL agenda should focus on the *design and study of fundamentally social systems* that are *informed by the affordances and limitations of technology*. (This wording was suggested by Nathan Dwyer.) CSCL systems should be fundamentally social because interactional and especially intersubjective epistemologies of learning require this. To be fundamentally social means that the technology should be designed specifically to mediate and encourage social acts that constitute group learning and lead to individual learning. To be informed by the affordances and limitations of technology means that the design attempts to leverage the unique opportunities provided by technology rather than replicating support for learning that could be done through other means, or (worse) trying to force the technology to be something for which it is not well suited.

There are many ways in which technology can be used to implement support for collaborative learning that are not intrinsic to technology itself. For example, consider the scripting of interactions (e.g., Weinberger et al., in press). We might study the effects of asking a group to go through phases of collaboration, or script the interaction at a finer grain, providing protocols for making and evaluating proposals. These interventions could just as well be done with paper, or even verbal instructions. There are clear advantages to using information technology, such as support for distance interaction and automated prompting, but the primary variable being studied is not itself a property of information technology (see also Dillenbourg, 2002). Such research is valuable and can be embraced within CSCL, but in my view is not at the core of the CSCL agenda.

More intrinsic to information technology as a topic of study is the generalized question of how the affordances of information technology can be appropriated to support intersubjective learning in action. What is unique to information technology that makes it potentially fill this role?

The computational medium is reconfigurable. Representations are dynamic: It is easy to move things around and undo actions. It is easy to replicate those actions elsewhere: one can bridge time and space. These features make information technology attractive as a "communication channel," but we exploit technology for its potential to make new communications possible, not try to force it to replicate face-to-faced interaction.

CMC turns communication into substance (Dillenbourg, in press). A record of activity as well as product can be kept, replayed, and even modified. We should explore the potential of the persistent record of communication and collaboration as a resource for intersubjective learning.

Computational media can analyze workspace state and interaction sequences, and reconfigure itself or generate prompts according to features of either. We should explore the potential of adaptive media as an influence on the course of intersubjective processes. We need not accept the anthropomorphism of the medium as "agent" or "coach" to take advantage of its ability to prompt, analyze and selectively respond.

Human communication and use of representational resources for this communication is highly flexible: we cannot "fix" meanings or even specify communicative tools (Dwyer & Suthers, submitted). Informed by this fact, CSCL research should identify the affordances of computational media and explore how these might be appropriated by collaborators, and in the process influence the course of that collaboration. We should view ourselves as designers of guides and affordances, not of deterministic procedures. The study of technology affordances should be undertaken with constant reference to the activity to be supported -- intersubjective meaning making or learning.

How To Study It?

I consider this question in terms of the major methodological traditions of CSCL and a specific analytic approach that is motivated by an operational definition of intersubjective learning.

A Call for Methodological Fusion

CSCL can presently be characterized as consisting of several disjoint methodological traditions: experimental, descriptive (ethnographic), and iterative design.

Many empirical studies follow the dominant experimental paradigm that compares an intervention against a control condition in terms of one or more variables. Data analysis in most of these studies is undertaken by "coding and counting": interactions are categorized and/or learning outcomes measured, and group means are

compared through statistical methods in order to draw generalizable conclusions about the effects of the manipulated variables on aggregate (average) group behavior. As discussed previously, typical analyses do not directly analyze the accomplishment of intersubjective learning. Such an analysis must examine the structure and intention of specific cases of interaction rather than count and aggregate behavioral categories.

The ethnographic tradition exemplified in CSCL by Roschelle (1994), Koschmann et al. (2003) and Koschmann, et al. (in press), is more suited for such case analyses. Video or transcripts of learners or other members of the community are studied to uncover the methods by which participants accomplish learning. The approach is data-driven, seeking to discover theoretical categories in the data rather than impose them in the analysis. The analysis is often microanalytic, examining on brief episodes in great detail. Descriptive methodologies are well suited to existentially quantified claims (e.g., that a community sometimes engages in a given practice). Yet, as designers we would like to make causal generalizations about the effects of design choices. Descriptive methodologies are less suited for claiming that an intervention has an effect, the province of the experimental methodology.

The traditional analysis methods of experimental psychology miss the methods through which learning is accomplished—intersubjective meaning making—but this does not imply that we should all become ethnographers. Rather, the foregoing considerations suggest a hybrid research methodology, drawing upon the strengths of both (Johnson & Onwuegbuzie, 2004). Experimental designs can continue to compare interventions, but the comparisons would be made in terms of microanalyses of how the features of information technology influence and are appropriated for members' methods for joint meaning-making. Conceptually, our analysis of process change from "coding and counting" to "exploring and understanding" ways in which design variables influence support for meaning-making. Such analyses are time intensive: we should explore instrumentation of our learning environments and automated visualization and querying of interaction logs as a research aid. Traditional analyses, especially measures of learning outcomes but also "coding and counting," might also be retained to obtain quick indicators of where more detailed analyses are merited, thereby focusing the detail work.

The design tradition is exemplified by Fischer & Ostwald (in press), Lingnau, et al. (2003) and Guzdial et al. (1997). Driven by the dialectic between theory and informal observations and engaging stakeholders in the process, they continuously improve the designs of artifacts intended to mediate learning and collaboration. Their research is not necessarily qualitative or quantitative, but may also be "quisitive" (Goldman, Crosby, Swan & Shea, 2004). Exploring design is a valuable component of the overall CSCL portfolio of research strategies. It is not enough to just observe people's behaviors and describe the contingencies of these behaviors with respect to technology affordances. We are trying to uncover the potential affordances of information technologies, so need to explore the "space" of possible designs, pushing into new areas and identifying promising features that should receive further study under the other methodological traditions. Designers also need to conduct microanalysis of collaborative learning with and through technology in order to identify designs that not only seem to be correlated with effective learning episodes, but also the affordances that are responsible.

A limitation of descriptive methodologies should be addressed. If we focus on finding examples of how members accomplish effective learning, we may miss abundant examples of how they also fail to do so. Yet in order to find something that is not there, we need to have an idea of what we are looking for. A purely data-driven approach that derives but never applies theory won't be adequate. Descriptive methods can be modified to address this need. Common patterns found in successful episodes subsequently become the theoretical categories we look for elsewhere, and perhaps do not find in instances of unsuccessful collaboration. Having identified where the successful methods were *not* applied, we can then examine the situation to determine what contingency was missing or responsible. Care should be taken, however, to make sure that in finding case examples where the interactional accomplishment of learning is absent we do not fail to notice where something else of value to the participants *is* being accomplished! For example, establishment and maintenance of individual and group identity are also worthwhile accomplishments as far as the participants are concerned (Whitworth et al., 2000).

Eclectic Analysis of Accretion of Interpretations

In my proposal, researchers from all methodological traditions will include microanalyses in their toolbox. How do we go about conducting our analyses, and what do we look for? In this final section I describe a framework that I am developing and so far have found to be useful. The framework is eclectic in that it can be used to apply a variety of epistemologies of collaborative learning and other theories. Its objective is to identify "accretions of interpretations," which I argue below is the core of intersubjective learning.

Intersubjective learning requires interactions between participants, so any analysis must begin by identifying the basic relation of *upatake* in which one participant takes up another's contribution and does something further with it. Contributions may include attentional orientation, information, and or expressions of attitude. We can find *uptake* in talk, and also in any other medium through which contributions are shareable. Examples of basic uptake relations include "A has said P, B has responded with Q," "A says P and B expresses (dis)agreement," "A brings O into the workspace, and B also begins to consider O," "A has created object O1; B has changed it to O2," "A has created O1 and B has created O2; now A combines O1 and O2 in such a manner," etc.

Once we have identified uptake relations, we need to interpret them in terms of how the participants have jointly accomplished something through them, and we need to identify the potential influence or utilization of technology affordances in having done so. What do we look for in order to identify what has been accomplished through the uptake? My answer involves a tentative commitment to what constitutes the core of intersubjective learning. I am currently operating under the working definition that knowledge construction is evidenced by the *accretion of interpretations of a dynamically evolving context*. Then, *collaborative* knowledge construction (including intersubjective learning) takes place when multiple participants contribute to this accretion of interpretations by building, commenting on, transforming and integrating the shared information base or context. The act of interpretation may take the form of explicit sense-making commentary, but it may also take place through the transformation and integration of representations of the information base. The important point is that *the joint accretion of interpretations is the gist of intersubjective learning* (not "going from unshared to shared information").

How then do we recognize instances of "accretions of interpretations"? What theory can tell us how to identify not only the means by which situations are problematized, but also how participants make sense of the situation and come to agreement on a course of action? Intersubjective learning and knowledge building involve multiple processes (see the model in Stahl, in press), and we may elect to support different aspects of these processes (as discussed in the first half of the paper). Therefore we should not expect one theory to do the entire job for us. An eclectic approach that "triangulates" from multiple theoretical perspectives is necessary due to the complexity of the problem we are tackling. We can draw upon various theories for insights on what counts as interpretive acts and what those acts mean for the learning of individuals and groups,

To exemplify this approach, I briefly recount the method of Suthers (2005). That study is analyzing participant's manipulations of a shared workspace during synchronous online collaboration in order to determine whether and how such actions can be understood as constituting "conversation" through the graphical representation being used, and if so whether knowledge construction is taking place. The strategy is hierarchical, similar to Mühlenbrock & Hoppe (1999). First, the basic observable actions taken by participants are identified, and uptake relations are identified. Then successively more inferential interpretations of the collaborative actions being accomplished through sequences of uptake relations are layered on this analysis.

For the identification of uptake relations, I looked first to Clark's contribution theory (Clark & Brennan, 1991). I restated grounding in terms of actions on a nonlinguistic (or semi-linguistic) representation: the analyst looks for *sequences of actions in which one participant's action on a representation is taken up by another participant in a manner that indicates understanding of its meaning, and the first participant signals acceptance.* I immediately encountered two problems. First, the final signal of acceptance is often implicit, so can be difficult to identify. For example, it can consist merely of continuing the interaction rather than initiating repair of a breakdown. Second, I realized that an analysis based solely on grounding theory at best can tell us only how people check that they have achieved mutual understanding, but does not inform us about the process by which this mutual understanding is reached. Therefore the theory will be of limited value in understanding what kinds of interactions lead to learning, and whether these are supported by our interventions. See Koschmann & LeBaron (2003) for further critiques of contribution theory, including a critique of whether the concept of "common ground" is defensible. However, I distinguish the claim that interlocutors (sometimes implicitly) signal acceptance of a contribution or initiate repair, and credit this perspective with suggesting to me that interaction through representations can be viewed as a form of nonverbal or semi-verbal conversation.

To take the next step towards understanding how learning is accomplished, I turned to the socially contextualized theories of learning. Representations that externalize one's beliefs can make beliefs explicit enough for one's interlocutors to notice conflicts, thereby initiating a socio-cognitive process of learning. Under the socio-cognitive conflict perspective (Doise & Mugny, 1984), I look for *situations in which the externalization of ideas led to identification of differences of interpretation that were subsequently taken up by at least one of the individuals involved*. In addition to overt verbal argumentation, clues that conflict is being addressed might include revision or deletion of the others' ideas or the use of an explicit conflict relation between one's own and others' ideas, if the representation provides for such relations.

The foregoing perspective is limiting in that it treats participants as separate cognitive entities that interact via language and (other) notations, yet retains the locale of knowledge construction activity within the individual. A distributed cognition perspective (Hollan, Hutchins & Kirsch, 2002) suggests that cognitive activities such as knowledge construction are distributed across individuals and information artifacts through and with which they interact. The information-transformative and interpretive components of a intersubjective learning can occur across multiple individuals via external representations. Under the distributed cognition perspective we would look for *transformations of representations across individuals where those transformations can be interpreted as an intersubjective cognitive process*. Examples include merging, revising, and connecting representations of ideas.

The activity theoretic perspective (Cole & Engestrom, 1993) considers how activity is formed within and changes a larger context that includes not only the self, the object or topic of interest, and tools such as the

external representations with which we are concerned, but also one's community, one's role in this community, and the norms for behavior in the community. I focused on the concept of *mediation*. When we examine the relationship between any two elements of an activity system (the subject, object, tool, community, roles, rules), we can sometimes benefit from asking how any third element mediates the relationship between the first two, influencing the form the relationship takes. For example, external representations can mediate between individual and community by crystallizing prior practice. Under a mediation perspective, I analyze collaborative use of representations by *looking for ways in which the representation mediates (makes possible and guides) interactions between participants*. My own prior work (Suthers & Hundhausen, 2003) builds on this theme. The creative acts afforded by a given representational notation may affect which negotiations of meaning and belief take place. I look for *discussions initiated as participants prepare to act upon a representation* and *identify ways in which participants use representations as a means of referring to ideas*.

This study is a work in progress, and there are other theories that can be applied to the process of generating the researchers' interpretations of uptake relations as evidence of participants' accumulating interpretations on their dynamically evolving context. It is my sense that we have at our disposal a powerful collection of theories of learning and social interaction. We have not yet fully explored the analytic power of this collection. I look forward to the further invention of new or uncovering of old theories that might provide fresh perspectives on the problems of CSCL. However, I would not want to see the field neglect to explore the power of our present theoretical toolkit as we rush to align our work with the new vogue theory of the year. It will take the next decade to work out the implications of those we already have at our disposal.

CONCLUSIONS

CSCL is a field that is establishing basic yet sometimes peripheral findings as it seeks its center. The orientation of the work being undertaken encompasses several epistemologies of collaborative learning, and leverages information technology as communication channel, as a constraining and guiding medium, and as a resource for collaboration. However, there is an emerging awareness that we need to grapple with the central and most unique problem of CSCL: processes of intersubjective learning, and how technological affordances mediate or support such processes. Small groups appear to be the richest and most fruitful unit for such study. A framework for analysis was offered that suggests interpretation of basic "uptake" actions in terms of the accretion of interpretations on a shared information base or context, examining how representational and other technological affordances guide action by offering potentials and constraints, and how affordances of the "substance" CMC makes out of communication can serve as resources for conversation, reflection, and group awareness.

Research methodology in CSCL is largely trichotomized between experimental, descriptive and exploratory design approaches. Although sometimes combined within a single research project, the methodologies are even then typically kept separate in companion studies or separate analyses of a single study. This situation can be productive for a little longer, as the experimentalists continue to identify variables that affect general parameters of collaborative behavior while the ethnographers identify patterns of joint activity that are essential to the meaning-making and learning we all seek to support. However, very soon CSCL needs experimentalists to study dependent variables that directly reflect the phenomenon of interest, the ethnographers to look for *predictive* regularities in technology mediated meaning making that can inform design, and the designers to generate and assess promising new technology affordances in terms of their mediation of meaning-making activities. Mutual assistance is possible through hybrid methodologies, for example applying richer descriptive analytic methods to the problem of understanding the implications of experimental manipulations and new designs and computer support for our own meaning-making activities as researchers.

This paper has been critical in places, but the critiques apply equally to my own current work and demand shifts in my own thinking. Perhaps these critiques also reflect impending shifts in our field—towards the study of practices of intersubjective learning and how these practices are mediated by technology affordances.

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