B. (THEORY TRACK): THE ROLE OF ARTIFACTS IN COLLABORATIVE LEARNING

Contributions to a Theoretical Framework for CSCL

Gerry Stahl

Fraunhofer Institute for Applied Information Technology – FIT, Germany
& University of Colorado at Boulder, USA
Gerry.Stahl@fit.fraunhofer.de
http://orgwis.gmd.de/~gerry

ABSTRACT

Looking at computer supported collaborative learning (CSCL) in terms of (a) collaborative knowledge building, (b) group and individual perspectives, (c) mediation by artifacts and (d) micro-analysis of conversation provides a rich, multi-dimensional starting point for conceptualizing and studying a specific variant of CSCL.

These four contributions to CSCL are inter-related. The notion of collaborative knowledge building defines a useful paradigm for conceptualizing learning as social practice. The social interactions and knowledge management activities in which shared knowledge is constructed can be analyzed as the result of interweaving group and personal conversational perspectives. In general, collaborative interaction is mediated by artifacts: sometimes only by transitory artifacts like spoken words or gestures, but increasingly by physical or digital artifacts and media. Empirical studies of collaborative knowledge building employing micro-ethnographic analysis of speech, gesture, artifacts and media can make the details of these collaboration interactions visible, highlighting the interplay of perspectives and artifacts in the trans-personal construction of knowledge.

A theoretical framework incorporating models of knowledge building, perspectives and artifacts – and grounded in empirical analysis of collaborative interaction – can guide the design of computer-based artifacts and media as support for collaborative learning with appropriate, elaborated and unified conceptualizations.

Keywords

Collaborative knowledge building, perspectives, artifacts, conversation analysis, computer support, theory, CSCL

INTRODUCTION

I would here like to introduce four themes that play major roles in the papers for CSCL 2002 (this volume). I have come to be convinced in my own work that these particular notions are important for thinking about computer supported collaborative learning (CSCL) and can contribute to a theoretical foundation for advancing the field:

- Collaborative knowledge building
- Group and individual perspectives
- Mediation by artifacts
- Interaction analysis

These themes have been developed in distinct academic literatures (e.g., education, psychology, activity theory and conversation analysis, respectively), but I believe they should be brought together for the kind of theoretical and methodological framework required by the complex and profoundly interdisciplinary field of CSCL.

I will present these themes in terms of four proposals – that would have to be investigated further in the future:

1. The term "knowledge building" is more concrete and descriptive than "learning" when we are interested in collaboration. It may also help to avoid the baggage of individualistic epistemology in favor of a social practice view.
2. Collaborative knowledge building is structured by the intertwining of group and personal perspectives. One should neither ignore nor fixate upon the role of individual minds, but see them in interaction with group understandings.
3. The construction of knowledge proceeds on the basis of artifacts already at hand – including linguistic, cognitive, cultural, physical and digital artifacts – and creates new artifacts to formulate, embody, preserve and communicate new knowledge.

4. Naturally occurring and carefully captured examples of collaborative knowledge building – such as video recordings of classroom interactions – can be rigorously analyzed to make visible the knowledge building activities at work, the intertwining of perspectives and the mediating role of artifacts.

To some extent, these four themes each fly in the face of conventional pedagogical wisdom – oriented toward mental contents of individual students – although they all have their respected advocates as well. Within the limited confines of this paper, I cannot defend them against all contenders while also demonstrating their relevance and importance to CSCL. I shall just try to motivate how they could help to clarify the domain of CSCL and define a specific approach within the field.

It should be noted at the outset that these are not intended as four independent theoretical claims; rather they contribute in a tightly interwoven way to a single framework or paradigm for thinking about CSCL. Collaborative knowledge building (theme a) moves away from approaches to learning focused on individual minds in two ways: first, by focusing on group activities, which necessarily include roles for individuals within the groups (theme b), and secondly by noting the importance of artifacts in the world, such as spoken, written or published texts that capture newly constructed knowledge (theme c). The evidence for these views can be found primarily in the kinds of micro-ethnographic studies of learning interactions that have recently become possible with the methods of conversation analysis using digital video (theme d). Conversely, when applied to CSCL such interaction analysis should be guided by (a) an interest in knowledge building activities, (b) an awareness of contrasting perspectives and (c) a focus on artifacts – without such guidance detracting from the intersubjective rigor of the analytic methodology. So the four contributions shed light on one another and together represent an integral contribution to theory.

One final point should perhaps be mentioned up front, rather than tacked onto the end as if in apology. That is, that the view of CSCL projected here is a visionary one. Collaborative knowledge building may be a way of life on the leading edge of scientific research, but it has proven devilishly hard to foster in contemporary school classrooms. The idea that new technologies will transform learning practices has not yet led to the collaborative ideal. The task of designing effective computer support along with appropriate pedagogy and social practices is simply much more complex than imagined. An explicit, elaborated, adopted and actualized theoretical framework is needed to (a) clarify the nature of collaborative knowledge building as a desired goal, (b) indicate how people can participate in it with concrete curricular approaches, (c) design tools to support it effectively in various contexts and (d) develop methods for observing and assessing it in practice.

Let us look a bit closer at each of the four proposed contributions to CSCL theory.

A. COLLABORATIVE KNOWLEDGE BUILDING

There are two troubling problems with the term "learning" if one wants to develop a theoretical framework for CSCL:

- Learning is everywhere; whenever someone engages in conscious activity, one can say that learning took place in someone's mind. In fact, even non-conscious activity can reinforce tacit competences.
- Learning is never seen; only the consequences of learning can be observed, and they generally turn out to be statistically insignificant when one tries to be rigorous about this (Russell, 1999). This approach to evaluating learning is a hold-over from behaviorist measurement of changes due to operant conditioning (drill and practice).

In contrast, the notion of "collaborative knowledge building" seems more tangible:

- It cannot simply be applied everywhere, but refers to specific, identifiable occurrences. Cases in which new knowledge is actually constructed by groups – rather than reified facts being recycled – are actually relatively rare in classrooms.
- With care and practice, one can directly and empirically observe the knowledge being built, because it necessarily takes place in observable media, like talk. Moreover, it produces knowledge objects or artifacts, which provide lasting traces and a basis for evaluating the knowledge building.

The term "knowledge building" is attributable to Scardamalia and Bereiter (1991), who have long advocated the restructuring of classrooms into knowledge building communities and who have spearheaded the development and testing of computer support for such communities (1996).

Their concept borrows explicitly from dominant forms of research in today's scientific communities, where theories are progressively developed through professional discourse and inscription (Latour & Woolgar, 1979) – involving, for instance, peer review and critique of papers published in conference proceedings. Here, a scientific community learns about its subject matter by collaboratively building knowledge in the form of documents that gradually define a path of inquiry and successively elaborate theory while also raising issues for future deeper investigation. Conflicting theoretical perspectives are essential to the process, as are the roles of specific participants. Discourse activities – such as questioning, proposing, arguing, critiquing, clarifying, negotiating, accusing, repairing, agreeing – are as important as the artifacts around which, through which and into which the discourse moves.

Not all important learning is collaborative knowledge building. Bereiter (2002) defines the latter in terms of the development of knowledge objects such as scientific concepts and theories. This does not include the learning of passed

down facts, of practical or social skills, or of techniques of learning itself. However, social discourse about ideas – the core of knowledge building – can certainly motivate and exercise skills like reading, writing and thinking as a side effect.

The thrust of collaborative knowledge building is to emphasize the construction and further development of a knowledge object that is shared by the group or "learning community." The focus is not on personal learning by the participants – who, it is assumed, retain some of what the group discovered, deepen their collaboration skills and enjoy positive experiences of inquiry and intellectual engagement – but on the growth of communal understanding as reflected in increasingly elaborate artifacts.[4]

Many models of curriculum design are compatible with collaborative knowledge building, and the elaboration of appropriate pedagogical practices remains an important area of active research. Progressive inquiry, for instance, dates back to analyses of problem solving by Dewey and Pierce. This has led us to an interrogative model of inquiry (Hakkarainen & Sintonen, 2001) based on an analysis of types of questioning according to the philosophy of science (e.g., Popper, Kuhn, Hintikka). A systematic approach to having groups of students pursue the posing and investigation of knowledge building questions is offered by problem-based learning, or PBL (Barrows, 1994). This approach tries to cover the breadth of a domain (such as medical education) – in addition to the depth gained through explorative inquiry – by providing a carefully designed set of cases as problems to be pursued consecutively.

PBL is thus a form of the case-based method (Collins & Stevens, 1983), but one which requires the student group to become self-reliant investigators, with the teacher or tutor only facilitating the small-group process. More generally, PBL is a specific approach to project-based learning (Blumenfeld et al., 1991), in which a group of students conducts a project. A potential issue with project-based activities that do not adhere to a model like PBL is that tasks often get divided up so that participants cooperate (as opposed to collaborate) on the over-all project but do not collaborate on the knowledge building; they may subsequently share their individual expertise through jig-sawing (Brown & Campione, 1994), but the basic knowledge building takes place outside the group interaction.

For a theoretically grounded approach to CSCL, we may want to focus on pedagogical approaches – like PBL – that center on group discussion as the core activity in inquiry. This discussion may take place verbally in face-to-face meetings. However, for the sake of providing computer support (e.g., searching capabilities or customizable displays) as well as to maintain persistence of the discourse for subsequent review and reflection, significant parts of the discussions should be captured textually on the computer network – as typed minutes, chat streams or discussion threads.

Because collaborative knowledge building necessarily involves the use in discourse of concepts whose meaning is continually changing and growing, a trained observer can (given the time and tools) observe how knowledge was built up step by step. Evidence exists in the interpretation of words, gestures and documents used. Because the knowledge was built by more than one participant, the changing understandings of the participants had to be shared with one another and may therefore be available to an outside observer as well. Roschelle (1996), for example, has provided an exemplary demonstration of this for a pair of collaborating high school physics students (see below).

The characteristics of collaborative knowledge building just reviewed – that it is typical in modern science, that it is rarely achieved in classrooms, that it can effectively motivate other forms of learning and that it can be observed in practice – suggest that it might provide a useful pedagogical focus for CSCL. Of course, the main attraction of the notion of collaborative knowledge building is the hope that computer support can significantly increase the ability of groups of students to build concepts, ideas, theories and understandings together.

B. GROUP AND PERSONAL PERSPECTIVES

After more than 2,500 years of knowledge building discourse about the nature of ideas and the meaning of meaning – dating back at least to the forum of Athens – we still find the concept of knowledge to be paradoxical and bewildering. However, two things seem clear:

- Wherever meaningful symbols, representations and artifacts may be found, they are only meaningful for individual minds. Interpretation is required, and that is necessarily carried out by individuals within the horizons of their personal perspectives (Gadamer, 1960/1988).
- Isolated from social interaction, physical artifacts and historical cultures, human brains are poor thinkers and could never have developed into powerful minds (Donald, 1991). In fact, it can be argued that modern minds are simply

[4] Koschmann, in his keynote address (this volume), would no doubt prefer the term "meaning-making" to "knowledge-building" because "knowledge" carries mentalistic connotations. But so does "meaning" – or any terms in which learning has been conceptualized in mainstream modern Western thought. Bereiter's (2002) focus on knowledge objects underlines their intersubjective, publicly accessible character. His unfortunate reliance on Popperian ontology is best replaced by an analysis of artifacts as physical objects embodying meaning.

> collections of cognitive artifacts internalized from inter-personal interactions (Vygotsky, 1930/1978). The mental is primordially a social or group phenomenon.

This means that anything like a theory of knowledge building must pay due regard to essential roles of both collaborative groups and their individual members.

The social basis of knowledge is deeply rooted. It is not just a matter of artifacts in the world extending the limited short-term memory of individual minds, like notes scattered about as external memory traces (Hutchins, 1996; Norman, 1993). Meaning arises in the historically given, social world. We are from the start situated in the shared, meaningful world into which we are born and with which we are engaged (Heidegger, 1927/1996). From the infant's first inkling of intentionality in the mother's gesture (Vygotsky, 1930/1978), to the moment of mutual human recognition (Hegel, 1807/1967; Mead, 1934/1962), to the world-transforming paradigm shifts of expansive learning (Engeström, 1999), meaning springs from inter-personal interaction.[5]

The dilemma between personal and group perspectives plays itself out on the theoretical plane as a dialectic of hermeneutic and social-cultural approaches. Hermeneutics, as the philosophy of interpretation, is concerned with how one can interpret the text of a distant author here and now. Heidegger's foundational analysis of human existence as an interpretive enterprise carried out on the basis of tacit, situated pre-understanding (1927/1996) appears at first sight to give priority to the individual as grantor of meaning. However, a critical closer reading shows that the individual is always essentially engaged in a shared world and that the network of meanings that define the individual's situation are historically, culturally, socially defined. Thus, in his influential explication of Heideggerian hermeneutic philosophy, Gadamer (1960/1988) argues that the possibility of understanding a distant text depends upon the author and interpreter sharing an historical horizon – one that includes the historical reception of the text itself within the cultural milieu that links author and reader.

The analysis that Gadamer applies to communication across the centuries is relevant to face-to-face conversation as well. Ethnomethodology (Garfinkel, 1967) stresses that the meaning of a communicative context is established interactively and is achieved by the participants creating a social order "on the fly." That is, the meaning of individual utterances is not given by some preconceived ideas represented in the speaker's mind or from her personal perspective, which are then expressed and conveyed in verbal symbols. Rather, the meaning of the utterances is negotiated by the speaking and responding parties; it exists only in the group perspective that is formed by the intertwining of personal perspectives in the communicative interaction itself. The meaning of a specific utterance may be defined and affected by subsequent utterances, responses, gestures, pauses, repairs, etc. (Sacks, 1992). That is, the meaning of statements made by individuals is constructed or achieved in the discourse of the group and forms the interpretive horizon in which knowledge is shared during the moment of interaction – regardless of whether or not we choose to attribute individual learning to the participants in the long run.

Discourse is the traditional medium of knowledge building. New ideas – and their interpretation by speakers and hearers – arise in the discourse in ways that transcend any individual's role:

> The mark of a really successful design or problem-solving meeting is that something brilliant comes out of it that cannot be attributed to an individual or to a combination of individual contributions. It is an emergent, which means that if you look at a transcript of the meeting you can see the conceptual object taking shape but you cannot find it in the bits and pieces making up the discourse. (Bereiter, 2002)

Clearly, each word in the discourse can trivially be attributed to an individual speaker. However, the meaning of that word is defined by its position in the discourse context, that is, by its relationship to arbitrarily many other words (by other individuals as well as by the word's speaker) and to the Gestalt meaning of the discourse as a whole, which is the group's, as we shall see in the next section.

In Roschelle's (1996) analysis of the physics students, for instance, their collaborative knowledge building coalesced in the phrase, "It pulls it." Roschelle was able to show that the students understood this to mean that the fat arrow (representing acceleration in their computer simulation) caused a specific kind of change to the other arrow (representing velocity). Within the context of their computer model of Newtonian mechanics this change had a predictable effect upon the movement of a particle – and the students understood this. The statement "It pulls it" is an elliptical, indexical statement that has little meaning on its own as an isolated sentence. In the context in which the students were collaborating, however, it amounted to the discovery of the physics principle that acceleration is "the derivative of velocity with respect to time." This latter way of stating it would not have made sense to these students, but only has meaning within the context of

[5] The inter-personal nature of learning is established in the relationship of a young child with his or her parents. The social can be very personal. Throughout the duration of my relationship with my parents, they motivated my attitude toward the generation of knowledge as social praxis. I wrote the Introduction to these Proceedings on November 19, 2001, the final day of my parents' living relationship to me, and in my mind this publication is dedicated to their memory.

Newton's theories of motion and calculus. The students' statement made sense to them in terms of the components in their computer simulation, their experience with the simulation, their previous discussion and their general world-knowledge of pulling.

When I analyzed a discourse among five middle school students and a teacher (Stahl & Sanusi, 2001), I was at first mystified by the cryptic interchanges in the transcript of a particularly intense and consequent collaborative moment. Within a matter of 30 seconds, the students exchanged 24 turns at speech, mostly consisting of sentence fragments or single words indicating disagreement or assent. It was clear that the students were intently engaged and shared a common understanding of what was taking place in the discourse: the resolution of a knotty problem for their collaborative inquiry and the achievement of a hard-fought consensus. But my retrospective interpretation of the transcript – which I developed in collaboration with experienced conversation analysts and others – required a careful reconstruction of the argumentation back several minutes as well as an understanding of the details of artifacts active in the knowledge building context. The meaning of a given utterance was not a simple function of the words used, the propositional content, the isolated speech act or even a conversational pair of utterances. Meaning was a shared, collaborative, interactive achievement. It was an ephemeral, rapidly evolving group perspective.

Of course, in this analysis I was also able to track the personal perspective and personality of each participant. The flow of discussion as well as the individual conversational moves derived from the individuals in some sense as well. With different participants contributing from different personal perspectives, the discourse would have been completely different. And yet, the actual knowledge building that took place had "a mind of its own." The group perspective, which unfolded and prevailed probably had more to do with the conceptual issues that were brought to the fore by the curriculum and by the artifacts which set the shared context and posed the problems to be discussed than with pre-existing ideas, intellectual orientations or personal values of the individual participants. So, while personal perspectives certainly contributed to the discourse and left observable traces there, the interaction achieved a group perspective that determined the meaning of individual contributions and within which knowledge was collaboratively built and comprehended.

C. MEDIATION BY ARTIFACTS

Knowledge building is mediated by artifacts. The interaction and interweaving of personal and group perspectives is mediated by artifacts. What does this mean? What is mediation and what are artifacts?

"Mediation" means that something happens by means of, or through the involvement of, a mediating object. For instance, when a student uses a technical term to construct knowledge or when a class of students uses a software collaboration system to discuss a theme, that term or that system is mediating the activity: It is providing a medium or middle ground through which the students interact with their ideas. The specific form of the mediation generally affects the nature of the activity profoundly, often determining the nature of the task itself, that is, the choice of medium can define the ends or goal as well as the possible means. In Roschelle's example, the metaphor of pulling mediated the students' knowledge building and allowed them to formulate a theory, to share their understanding of how the simulation worked, to bring their bodily skills to bear, and to solve some but not all of the challenges posed by the teacher.

An artifact is a meaningful object created by people for specific uses. The term "pull" – as elaborated metaphorically by the students and as operationalized by them in manipulating the computer simulation of accelerating forces – functioned as a knowledge building artifact on several levels: It was a pre-understood concept that they could build upon, it provided a tool that they could use for collaborative thinking about the simulated phenomena and it resulted in a knowledge object that incorporated their new shared understanding.

The concept of artifact is perhaps most familiar in anthropology, where it refers to discovered objects that were made by ancient people and that still display traces of their intended function or symbolic import. Hegel (1807/1967) spoke of artifacts as objects on which meaningful form had been imposed and he situated the primordial act of artifact creation in the interpersonal interaction in which people recognize each other and themselves as self-conscious actors. Marx (1844/1967; 1867/1976) took the analysis of artifacts another step to argue that their character was largely determined by prevailing socio-economic relations, so that in our age most artifacts are produced as commodities for monetary exchange. For Hegel, artifacts retain the externalized subjectivity in physical form, and for Marx they retain both concrete human labor that went into producing them and the abstract value of the labor time they required.

These classic analyses of mediation and artifacts are relevant to a contemporary CSCL theory. While theory is now a trans-disciplinary undertaking drawing upon multiple traditions in the social, human and natural sciences, the concepts of mediation and artifact can be traced back to the philosophy of Hegel, whose dialectical analyses revealed the mediated and historical dynamic everywhere. Marx critiqued idealist and subjectivist aspects of Hegel's thought and grounded the mediations in concrete analyses of historically-specific social relationships. Contemporary theories prevalent in CSCL can be traced back to their roots in Hegel and Marx or later developments based on Vygotsky (e.g., activity theory), Heidegger (e.g., situated theory) or Dewey (e.g., inquiry theory).

Vygotsky (1930/1978; 1934/1986) wanted to supplement Marx's social theory with a psychology of mediated cognition (a perspective on the individual as intertwined with the group perspective). He extended the notion of physical artifact (tool) to encompass linguistic artifacts (symbols) as well. The individual's activity was then seen to be mediated by both varieties of artifact. The human ability to use physical and linguistic artifacts is a cultural development that allowed mankind to evolve beyond its biological basis.

Vygotsky argued – on the basis of empirical psychology experiments – that the meaning of artifacts and our understanding of that meaning are first created in inter-personal contexts, such as mother and child or teacher and student, and subsequently may be appropriated and internalized in an individual mind. The discussion of learning in a student's "zone of proximal development," scaffolded by a teacher, is based on this. We can call the internalized result of this process a "cognitive artifact." For instance, a work group might develop a list of tasks or a diagram of a work flow on a white board and a member of the group might then internalize and later mentally recall that list or diagram in order to monitor future work. The internal mental representation is then a cognitive artifact that resulted from group knowledge building and that may mediate subsequent knowledge building by the individual or the group. In this analysis, the mental representation is a result of collaborative activities and did not first arise subjectively to then be expressed externally. (The deconstruction of artifacts often shows that things developed in the opposite order from how they now appear – that is characteristic of the reification of meaning in an artifact.)

A complete working out of Vygotsky's approach could portray the human mind as nothing but a growing set of cognitive artifacts, appropriated and internalized by each of us in our personal development from our interactions with those around us and our embeddedness in our cultural world. Vygotsky and others who investigate infant development have suggested how even the most basic senses of intentionality, meaning and intersubjectivity may arise in interpersonal interaction – as sketched by Hegel theoretically. The folk theories of mind – roundly criticized by Bereiter (2002), Dennett (1991) and others – can be viewed as metaphors (mind as a container of ideas, a theater of experiences, a homunculus mind within the mind) which may have served their purpose but have now outlived their usefulness. Minksy (1986), for instance, has proposed an alternative "society of mind" metaphor to capture the computational structure of mind as a decentralized set of cognitive artifacts.

If we adopt a Vygotskian view of mediation by artifacts, then the knowledge building process can be conceptualized as the construction of knowledge artifacts, involving physical and symbolic artifacts as starting point, as medium and as product. The process proceeds collaboratively and intersubjectively, within a socio-cultural context. The final knowledge artifact may be internalized by one or more of the participants. While the internalized learning outcomes may be problematic to assess, the shared understanding within the collaborative knowledge building is experienced by the participants and may be subject to reconstruction from traces left in various artifacts, including video recordings and their transcripts.

The task of education in this approach is to revive meanings that have been captured and preserved in artifacts. This is the problem of cultural transmission. Culture can be conceptualized as a body of cognitive and other artifacts. In literate society, for instance, culture includes systems of numbers and written language. Schooling is largely the attempt to help young students to internalize the vast repertoire of meaning that has been associated with these artifacts. Although it is often possible for individuals who have mastered certain skills (cognitive artifacts) to develop related knowledge artifacts on their own, it is at other times useful to recreate the intersubjective conditions of knowledge creation in carefully structured contexts of collaboration with well-designed mediational artifacts to scaffold further learning. Within CSCL efforts, this would mean designing software to support the right kinds of interpersonal interaction, of mediation by artifacts and of knowledge artifact construction.

One does not have to buy Vygotsky's whole approach as sketched out here in order to recognize the importance of an analysis of mediation and of artifacts for a theoretical framework for CSCL. Such an understanding of artifacts as humanly meaningful physical objects can, for instance, overcome Bereiter's (2002) dependence upon Popper's questionable "third world" ontology of knowledge objects. Perhaps the most urgent undertaking at this time is further empirical investigation of how artifacts and their understanding actually function in concrete instances of collaborative knowledge building. For this we need a methodology of interaction analysis.

D. INTERACTION ANALYSIS

Roschelle presented his analysis of two students working with a physics micro-world simulation as an instance of student learning as conceptual change, facilitated by collaborative use of a computer artifact. One could reconceptualize his analysis as an attempt by the students to rediscover the meaning or affordances that were designed into the software artifact as a model of physics. The term "pull" which they interpreted and developed in this connection was a linguistic artifact that they collaboratively constructed as a knowledge object and then individually internalized as an expression of their group learning. Roschelle used conversation analysis of video tapes as well as interviews of the students to conduct his study of the collaborative knowledge building and the internalized conceptual change.

The question of how people rediscover meaning in artifacts is an important and difficult problem. When artifacts are created, their meaning is shared and relatively accessible. The artifact functions importantly to capture, formulate and encapsulate that meaning. But the meaning does not remain simply available on the surface of the artifact. As a note in the discussion database from my seminar on artifacts put it,

> *Thoughts on meaning in artifacts* by Bob Craig on Dec. 12, 2000
>
> Do artifacts "embody meaning" or do they embody meaningful traces of human activity? … Meaning is not "in" the artifact; rather it is "in" the total situation that includes artifacts, minds and social practices.

The meaningful traces transform, reify, distort and hide the meanings that originally existed in the live human interactions. New minds who encounter the artifacts must recreate the appropriate social practices, reconstruct the cultural contexts and rediscover the meaning within their own personal and group perspectives.

To investigate how people disclose the meaning of artifacts that they do not understand, I undertook an analysis of a specific computational cognitive artifact. I looked at how the five middle school students referred to in Section B above struggled to uncover the structures designed into a rocket simulation. I started by trying to follow the students' knowledge building discussion in a transcript of their discourse. But the most interesting and intense collaborative discussion was particularly hard to interpret. The student utterances did not assume the explicit form of scientific propositions of articulate arguments. Nor could the conversational turns be coded as coherent speech acts (Searle, 1969).

Here is the transcript of the pivotal moment of the three-hour long project with the rocket simulation:

1:22:05	Brent	This one's different
1:22:06	Jamie	Yeah, but it has same no…
1:22:07		(1.0 second pause)
1:22:08	Chuck	… Pointy nose cone
1:22:09	Steven	Oh, yeah
1:22:10	Chuck	But it's not the same engine
1:22:11	Jamie	Yeah it is …
1:22:12	Brent	… Yes it is
1:22:13	Jamie	⌈ Compare two 'n' one
1:22:13	Brent	⌊ Number two
1:22:14	Chuck	I know
1:22:15	Jamie	Are the same
1:22:16	Chuck	Oh

These one-second utterances make little sense on their own. They are elliptical and indexical – like Rochelle's "It pulls it." By "elliptical" I mean that these are primarily sentence fragments, phrases that may complete or be completed by another student's utterance, but do not stand on their own. They are fragments of a discussion that is only meaningful at the group level. By "indexical" or "deictic" I mean that they point to or intend something without explicitly stating their referent ("it," "this one"). They index important elements of the shared situation that it would be redundant or superfluous to name. Where words and phrases are repeated, the repetitions play important roles of indicating agreement and shared understanding, which is also signified by the way utterances tend to complete each other.

The discourse is only meaningful on the group level, where the meaning spans individual utterances of individuals and even conversational pairs. The meaning is integrally situated in the temporally unfolding group activity, centered on the simulation artifact (Vikkunen & Kuutti, 2000).

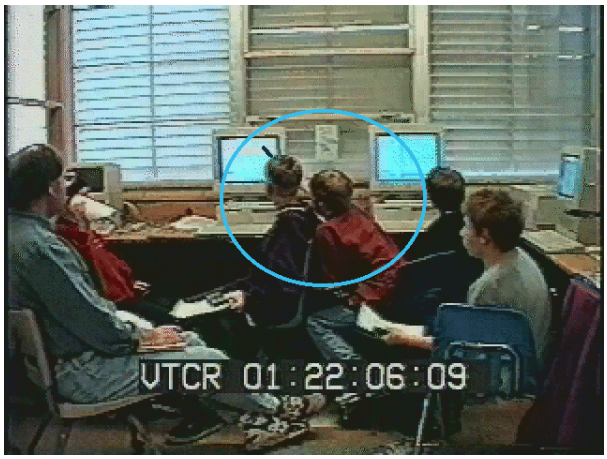

Figure 1. Students discuss a computer simulation artifact.

To understand what took place in this ten seconds, one must reconstruct the argument that reaches its climax here but that was set up in the previous ten minutes. (A theoretical foundation for this is given by Bakhtin (1986), who argues that an utterance is only meaningful in terms of its references back to preceding utterances to which it responds and forward to anticipated responses of a projected audience, and by Heidegger (1927/1996), who situates meanings within the extended dimensions of human temporality.) One must also understand the task of the three-hour project and analyze the affordances of the software artifacts that the students are working with. (Activity theory, as formulated by Engeström (1999), proposes general structures of the broader effective

context, including societal dimensions as well as the goals and tools of group activities.) In addition, it is necessary to observe closely the bodily orientations, gaze and gestures of the students.

In Fig. 1, Brent (circled) thrusts his body forward and shifts the group's focus to a rocket description on the monitor, about which he says "This one's different." The ensuing discussion debates what is the same and what is different about this rocket. The rocket to which "this one" is compared actually shifts here ("compare two 'n' one"), and that shift enlightens Chuck, who has resisted the teacher and the peer group, and has long tried to promote his personal perspective. Now, his "Oh" acknowledges a new-found acceptance of the group perspective.

A detailed analysis of this transcript would make visible the knowledge building process that took place, in which the students displayed for each other verbally and non-verbally their shifting understandings and interactively achieved the creation of shared meaning. This meaning was partially encapsulated in terms like "same" and "different," that took on specific functions in their collaboration.

More generally, the elements of this kind of interaction analysis have been developed on a rigorous methodological basis by the theory of ethnomethodology (Garfinkel, 1967) and the science of conversation analysis (CA) (Sacks, 1992). With the availability of digital video to capture and facilitate detailed analysis of naturally occurring interpersonal interaction, the CA approach has been combined with the study of gesture, gaze, bodily orientation, etc. into techniques for interpreting detailed behavior known as micro-ethnography (LeBaron & Streeck, 2000; Streeck, 1983). Most communication analysis in this tradition has studied pairs or small groups in face-to-face situations without technological mediation, although studies of telephone conversations played a major role in the early years of CA (Hopper, 1992; Sacks, 1992). However, the foregoing observations on the rocket simulation discourse suggest that such methods can be applied to CSCL situations as well – with appropriate adaptation. If this is done, attention must be paid to the central mediational role of digital as well as linguistic artifacts. Also, in cases of collaborative knowledge building the unit of analysis for meanings should take into account the intertwining of personal and group perspectives by interpreting individual utterances as elements of the larger discourse and activity.

CSCL FOUNDATIONS AND APPLICATIONS

A theory for CSCL should help us to think about collaborative learning, to structure pedagogy, to design software media and to study actual occurrences of knowledge building inside and outside of classrooms. I think the four foundational themes discussed here start to address these needs. The notion of knowledge building focuses us on activities associated with knowledge management and the further development of theories. A concern with the intertwining of personal and group perspectives suggests curricular approaches and classroom practices that integrate individual and team efforts. The analysis of artifacts conceptualizes the roles of CSCL systems and their databases as mediators and preservers within processes of creating knowledge objects. Finally, interaction analysis allows one to view and assess the knowledge building activities, the intertwining of perspectives and the mediation by artifacts.

The need for these four theoretical contributions arose for me in my work designing and deploying a CSCL software system named `WebGuide` (Stahl, 2001). This system prototyped knowledge creation and knowledge management functions that extended a conventional discussion forum. `WebGuide` investigated methods for intertwining notes in personal and group perspectives, that provided interlinked organizations of shared ideas. The effort to reflect upon the nature of the `WebGuide` software I was designing led me to a view of it as a mediating artifact. Rather than trying to analyze the complex interactions of a class using `WebGuide`, I started by looking at how students learned about a simpler digital artifact, `SimRocket` (Stahl & Sanusi, 2001) – and that led me to a growing fascination with conversation analysis and micro-ethnography. I believe that the theoretical framework that emerged from my work on `WebGuide` will prove valuable in designing and deploying the next system I will be working on, `BSCL` (Leinonen et al., 2001). Perhaps it can help others as well.

ACKNOWLEDGEMENTS

The ideas in this paper grew out of collaborative knowledge building mediated by `WebGuide` in a series of seminars on CSCL at the University of Colorado. I would particularly like to thank participants Alena Sanusi, Curt LeBaron and Bob Craig from the Communication Department as well as the teachers and students at Platt Middle School in Boulder who were involved with `SimRocket`. The paper was written during my transition from L^3D in USA to the GMD and the ITCOLE Project in Europe, and therefore owes much to my long-time colleagues in Colorado.

REFERENCES

Bakhtin, M. (1986) *Speech Genres and Other Late Essays,* (V. McGee, Trans.), University of Texas Press, Austin, TX.

Barrows, H. (1994) *Practice-based Learning: Problem-Based Learning Applied to Medical Education,* SIU School of Medicine, Springfield, IL.

Bereiter, C. (2002) *Education and Mind in the Knowledge Age,* Lawrence Erlbaum Associates, Hillsdale, NJ.

Blumenfeld, P., Soloway, E., Marx, R., Krajcik, J., Guzdial, M., & Palincsar, A. (1991) Motivating project-based learning: Sustaining the doing, supporting the learning, *Educational Psychologist,* 26 , pp. 369-398.

Brown, A. & Campione, J. (1994) Guided discovery in a community of learners. In K. McGilly (Ed.) *Classroom Lessons: Integrating Cognitive Theory and Classroom Practice,* MIT Press, Cambridge, MA, pp. 229-270.

Collins, A. & Stevens, A. R. (1983) Goals and strategies of inquiry teachers. In R. Glaser (Ed.) *Advances in Instructional Psychology,* Lawrence Erlbaum Associates, Hillsdale, NJ.

Dennett, D. C. (1991) *Consciousness Explained,* Little Brown and Company, Boston, MA.

Donald, M. (1991) *Origins of the Modern Mind: Three Stages in the Evolution of Culture and Cognition,* Harvard University Press, Cambridge, MA.

Engeström, Y. (1999) Activity theory and individual and social transformation. In Y. Engeström, R. Miettinen, & R.-L. Punamäki (Eds.), *Perspectives on Activity Theory,* Cambridge University Press, Cambridge, UK, pp. 19-38.

Gadamer, H.-G. (1960/1988) *Truth and Method,* Crossroads, New York, NY.

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

Hakkarainen, K. & Sintonen, M. (2001) The interrogative model of inquiry and computer-supported collaborative learning, *Science & Education,* in press .

Hegel, G. W. F. (1807/1967) *Phenomenology of Spirit,* (J. B. Baillie, Trans.), Harper & Row, New York, NY.

Heidegger, M. (1927/1996) *Being and Time: A Translation of Sein und Zeit,* (J. Stambaugh, Trans.), SUNY Press, Albany, NY.

Hopper, R. (1992) *Telephone Conversation,* Indiana University Press, Bloomington, IN.

Hutchins, E. (1996) *Cognition in the Wild,* MIT Press, Cambridge, MA.

Latour, B. & Woolgar, S. (1979) *Laboratory Life,* Sage Publications, Thousand Oaks, CA.

LeBaron, C. & Streeck, J. (2000) Gesture, knowledge and the world. In D. McNeill (Ed.) *Language and Gesture,* Cambridge University Press, Cambridge, UK.

Leinonen, T., Hakkarainen, K., Appelt, W., Dean, P., Gómez-Skarmetav, A., Ligorio, B., Lipponen, L., Merisaari, L., Mielonen, S., Pontecorvo, C., Sligte, H., & Vosniadou, S. (2001) ITCOLE Project: Designing innovative technology for collaborative learning and knowledge building, In: Proceedings of *Ed-Media 2001: World Conference on Educational Multimedia, Hypermedia and Telecommunications*, Tampere, Finland.

Marx, K. (1844/1967) Alienated labor. In L. G. K. Easton (Ed.) *Writings of the Young Marx on Philosophy and Society,* Doubleday, New York, NY, pp. 287-300.

Marx, K. (1867/1976) *Capital, Volume I,* (B. Fowkes, Trans.), Vintage, New York, NY. Available at: http://www.marxists.org/archive/marx/works/1867-c1/index.htm.

Mead, G. H. (1934/1962) *Mind, Self and Society,* University of Chicago Press, Chicago, IL.

Minsky, M. (1986) *Society of Mind,* Simon & Shuster, New York, NY.

Norman, D. A. (1993) *Things That Make Us Smart,* Addison-Wesley Publishing Company, Reading, MA.

Roschelle, J. (1996) Learning by collaborating: Convergent conceptual change. In T. Koschmann (Ed.) *CSCL: Theory and Practice of an Emerging Paradigm,* Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 209-248.

Russell, T. (Ed.) (1999) *The No Significant Difference Phenomenon,* Mindspring Press. Available at: http://cuda.teleeducation.nb.ca/nosignificantdifference/.

Sacks, H. (1992) *Lectures on Conversation,* Blackwell, Oxford, UK.

Scardamalia, M. & Bereiter, C. (1991) Higher levels of agency in knowledge building: A challenge for the design of new knowledge media, *Journal of the Learning Sciences,* 1 , pp. 37-68.

Scardamalia, M. & Bereiter, C. (1996) Computer support for knowledge-building communities. In T. Koschmann (Ed.) *CSCL: Theory and Practice of an Emerging Paradigm,* Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 249-268.

Searle, J. (1969) *Speech Acts: An Essay in the Philosophy of Language,* Cambridge University Press, Cambridge, UK.

Stahl, G. (2001) WebGuide: Guiding collaborative learning on the Web with perspectives, *Journal of Interactive Media in Education,* 2001 (1). Available at: www-jime.open.ac.uk/2001/1 and http://orgwis.gmd.de/~gerry/publications/journals/jime2001/webguide.pdf.

Stahl, G. & Sanusi, A. (2001) Multi-layered perspectives on collaborative learning activities in a middle school rocket simulation project, In: Proceedings of *22nd Annual Ethnography in Education Research Forum*, Philadelphia, PA. Available at: http://orgwis.gmd.de/~gerry/publications/conferences/2001/ethnography2001/ethnography.pdf.

Streeck, J. (1983) *Social Order in Child Communication: A Study in Microethnography,* Benjamins, Amsterdam, NL.

Vikkunen, J. & Kuutti, K. (2000) Understanding organizational learning by focusing on "activity systems", *Accounting, Management and Information Technologies,* 10 , pp. 291-319.

Vygotsky, L. (1930/1978) *Mind in Society,* Harvard University Press, Cambridge, MA.

Vygotsky, L. (1934/1986) *Thought and Language,* MIT Press, Cambridge, MA.