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Shared Meaning, Common Ground, Group Cognition

Socio-cultural theories drawn upon in previous chapters suggest that cognition and learning take place at the level of groups and communities as well as individuals. Various positions on the nature of shared meaning have been proposed and a number of theoretical perspectives have been recommended in the CSCL literature. In particular, the concept of common ground has been developed to explain how meanings and understandings can be shared by multiple individuals. This chapter takes a critical look at the concepts of shared meaning and common ground as they are generally used, and proposes an empirical study of how group cognition is constituted in practice.

The notion of group cognition is defining of the approaches of CSCW and CSCL. In the most influential attempt to define the CSCL paradigm of research, Koschmann (1996a) argues that forms of instructional technology research prior to CSCL "approach learning and instruction as psychological matters (be they viewed behavioristically or cognitively) and, as such, are researchable by the traditional methods of psychological experimentation" (p. 10f). That is, they focus on the behavior or mind of the individual student as the unit of analysis when looking for instructional outcomes, learning, meaning making or cognition. By contrast, the paradigm of CSCL "is built upon the research traditions of those disciplines—anthropology, sociology, linguistics, communication science—that are devoted to understanding language, culture and other aspects of the social setting" (p. 11). This radical paradigm shift, focusing on "the social and cultural context as the object of study, produces an incommensurability in theory and practice relative to the paradigms that have come before" (p.13).

The incommensurability between CSCL and other paradigms of instructional technology becomes clear if we phrase it this way: in the CSCL perspective, it is not so much the individual student who learns and thinks, as it is the collaborative group. Given that we have, over the millennia, become used to viewing learning and thinking as activities of individual minds, it is hard to conceive of them as primarily group activities. Of course, this approach does not deny that *individuals often think and learn on their own*, but rather that *in situations of collaborative activity it is informative to study how processes of learning and cognition take place at the group level as well*. In fact, such analysis often demonstrates that even when someone learns or thinks in seeming isolation, this activity is essentially conditioned or mediated by important social considerations.

Koschmann points out that Vygotsky—one of the primary theoretical sources for CSCL—proposed the "zone of proximal development" as "a mechanism for learning on the inter-psychological plane" (p.12). Vygotsky (1930/1978) contrasted his conception of development at the group level to the traditional psychological focus on individual learning, saying, "In studies of children's mental development it is generally assumed that only those things that children can do on their own are indicative of mental abilities" (p. 85). Vygotsky's alternative social conception of development was meant to measure a

child's position in the "*process by which children grow into the intellectual life of those around them*" (p. 88; italics in original), as opposed to their mental position in doing tasks on their own. The italicized phrase is strikingly similar to the definition of situated learning in Lave & Wenger (1991)—another central source of CSCL's theory of learning. Related foundations of the CSCL paradigm include Hutchins' (1996) presentation of distributed cognition and Suchman's (1987) discussion of situated action.

Chapter 16 drew on these and other sources to argue for taking meaning that is constructed in successful processes of collaboration as a shared group product, which is, however, subject to interpretation by the individuals involved. As much as the writings on situated action, distributed cognition, social constructivism, activity theory, social practice, etc. have foregrounded the social nature of learning and thinking, it is still hard to overcome our individualistic conceptual traditions and come to terms with group learning or group cognition. This chapter is an attempt to further that effort.

The Problem of Shared Meaning

The analysis in chapter 16 tried to provide insight into the nature of the *group perspective*. It argued for a view of both shared group *meaning* and individual *interpretation*. Shared meaning was not reduced to mental representations buried in the heads of individuals. Such mental contents could only be inferred from introspection and from interpretation of people's speech and behavior, whereas socially shared meaning can be observed in the visibly displayed discourse that takes place in group interactions including non-verbal communication and associated artifacts. This approach does not result in a behaviorist denial of human thought in bracketing out inferred mental states and focusing on observable interaction, because of the methodological recognition of interpretive perspectives. People are considered to be interpreting subjects, who do not simply react to stimuli but understand meanings.

It is true that only individuals can interpret meaning. But this does not imply that the group meaning is just some kind of statistical average of individual mental meanings, an agreement among pre-existing opinions, or an overlap of internal representations. A group meaning is constructed by the interactions of the individual members, not by the individuals on their own. It is an emergent property of the discourse and interaction. It is not necessarily reducible to opinions or understandings of individuals. Chapter 12 presented an example of how this works. The discourse transcribed there is strikingly elliptical, indexical and projective; that means that each utterance implies and requires a (perhaps open-ended) set of references to complete its meaning. These references are more a function of the history and circumstances of the discourse than of intentions attributable to specific participants. The words in the analyzed collaborative moment refer primarily to each other, to characteristics of the artifacts discussed and to group interactions. In fact, we can only attribute well-defined opinions and intentions to the individual students after we have extensively interpreted the meanings of the discourse as a whole.

Of course, it is not only possible but also habitual to attribute thoughts and intentions to individual actors. We assume that a speaker's words are well-defined in advance in the speaker's mind and that the discourse is just a way for the speaker to express some preconceived meaning and convey it to the listeners. This reveals a conflict. If meaning is

socially constructed and shared, why do we feel compelled to treat it as private property; if it takes place in isolated minds, how can it ever be shared and understood collaboratively? The possibility of shared meaning must be somehow explained. This is particularly important in cases of collaborative learning, where the knowledge that is constructed must be shared among the learners.

The term "shared knowledge" is ambiguous. It can refer to:

- Similarity of individuals' knowledge: the knowledge in the minds of the members of a group happen to overlap and their intersection is "shared."
- Knowledge that gets shared: some individuals communicate what they already knew to the others.
- Group knowledge: knowledge is interactively achieved in discourse and may not be attributable as originating from any particular individual.

The ambiguity of this term corresponds to different paradigms of viewing group interaction: whether it is taken to be reducible to knowledge held by individual thinkers or to be an emergent property of the group discourse as an irreducible unit for purposes of analysis.

A Conflict of Paradigms

Research on learning and education is troubled to its core by the conflict of the paradigms we are considering. Sfard (1998) reviewed some of the history and consequences of this conflict in terms of the incompatibility of the acquisition metaphor (AM) of learning and the participation metaphor (PM). AM conceives of education as a transfer of knowledge commodities and their subsequent possession by individual minds. Accordingly, empirical research in this paradigm looks for evidence of learning in changes of mental contents of individual learners. PM, in contrast, locates learning in intersubjective, social or group processes, and views the learning of individuals in terms of their changing participation in the group interactions. AM and PM are as different as day and night, but Sfard argues that we must learn to live in both complementary metaphors.

The conflict is particularly pointed in the field of CSCL. Taken seriously, the term "collaborative learning" can itself be viewed as self-contradictory given the tendency to construe learning as something taking place in individual minds. Having emerged from the paradigm shift in thinking about instructional technology described by Koschmann (1996a), the field of CSCL is still enmeshed in the paradigm conflict between opposed cognitive and socio-cultural focuses on the individual and on the group (Kaptelinin & Cole, 2002). In his keynote at the CSCL '02 conference, Koschmann (2002b) argued that even exemplary instances of CSCL research tend to adopt a theoretical framework that is anathema to collaboration. He recommended that talk about "knowledge" as a thing that can be acquired should be replaced with discussion of "meaning making in the context of joint activity" in order to avoid misleading images of learning as mental acquisition and possession of knowledge objects.

Although Koschmann's alternative phrase can describe the intersubjective construction of shared meanings achieved through group interaction, the influence of AM can re-construe meaning making as something that must perforce take place in individual

human minds because it is hard for most people to see how a group can possess mental contents. Chapter 16 argued in effect that both Koschmann's language and that of the researchers he critiqued is ambiguous and is subject to interpretation under either AM or PM. A simple substitution of wording is inadequate; it is necessary to make explicit when one is referring to individual subjective understanding and when one is referring to group intersubjective understanding—and to make clear to those under the sway of AM how intersubjectivity is concretely possible.

The problem with recommending that researchers view learning under both AM and PM, or that they be consistent in their theoretical framing, is that our common sense metaphors and widespread folk theories are so subtly entrenched in our thinking and speaking. The languages of Western science reflect deep-seated assumptions that go back to the *ideas* of Plato's *Meno* (350 BC/1961) and the *ego cogito* of Descartes' *Meditations* (1633/1999). It is hard for most people to imagine how a group can have knowledge, because we assume that knowledge is a substance that only minds can acquire or possess, and that only physically distinct individuals can have minds (somewhere in their physical heads). The term *meaning* as in *shared meaning* carries as much historical baggage as the term *knowledge* in *knowledge building*.

The Range of Views

CSCL grows out of research on cooperative learning that demonstrated the advantages for individual learning of working in groups (e.g., Johnson & Johnson, 1989), but had not yet made the socio-cultural paradigm shift. There is still considerable ambiguity or conflict about how the learning that takes place in contexts of joint activity should be conceptualized. While it has recently been argued that the key issues arise from ontological and epistemological commitments deriving from philosophy from Descartes to Hegel (Koschmann, 2002c; Packer & Goicoechea, 2000), I have argued in previous chapters that it is more a matter of focus on the individual (cognitivist) versus the group (socio-cultural) as the unit of analysis. Theoretical positions on the issue of the unit of learning—e.g., in the compilations of essays on shared cognition (Resnick, Levine, & Teasley, 1991) or distributed cognition (Solomon, 1993)—take on values along a continuous spectrum from individual to group:

- Learning is always accomplished by individuals, but this individual learning can be assisted in settings of collaboration, where individuals can learn from each other.
- Learning is always accomplished by individuals, but individuals can learn in different ways in settings of collaboration, including learning how to collaborate.
- Groups can also learn, and they do so in different ways from individuals, but the knowledge generated must always be located in individual minds.
- Groups can construct knowledge that no one individual could have constructed alone by a synergistic effect that merges ideas from different individual perspectives.
- Groups construct knowledge that may not be in any individual minds, but may be interactively achieved in group discourse and may persist in physical or symbolic artifacts such as group jargon or texts or drawings.
- Group knowledge can be spread across people and artifacts; it is not reducible to the knowledge of any individual or the sum of individuals' knowledge.

- All human learning is fundamentally social or collaborative; language is never private; meaning is intersubjective; knowledge is situated in culture and history.
- Individual learning takes place by internalizing or externalizing knowledge that was already constructed inter-personally; even modes of individual thought have been internalized from communicative interactions with other people.
- Learning is always a mix of individual and group processes; the analysis of learning should be done with both the individual and group as units of analysis and with consideration of the interplay between them.

The different positions listed above are supported by a corresponding range of theories of human learning and cognition. Educational research on small group process in the 1950's and 1960's maintained a focus on the individual as learner (e.g., Johnson & Johnson, 1989; for a review see Stahl, 2000). Classical cognitive science in the next period continued to view human cognition as primarily an individual matter—internal symbol manipulation or computation across mental representations, with group effects treated as secondary boundary constraints (Simon, 1981; Vera & Simon, 1993). In reaction to these views, a number of socio-cultural theories have become prominent in the learning sciences in recent decades. To a large extent, these theories have origins in much older works that conceptualized the situated-ness of people in practical activity within a shared world (Bakhtin, 1986a; Heidegger, 1927/1996; Husserl, 1936/1989; Marx, 1867/1976; Schutz, 1967; Vygotsky, 1930/1978). Here are some representative theories that focus on the group as a possible unit of knowledge construction:

- *Collaborative Knowledge Building*. A group can build knowledge that cannot be attributed to an individual or to a combination of individual contributions (Bereiter, 2002).
- *Social Psychology*. One can and should study knowledge construction at both the individual and group unit of analysis, as well as studying the interactions between them (Resnick *et al.*, 1991).
- *Distributed Cognition*. Knowledge can be spread across a group of people and the tools that they use to solve a problem, and can emerge through their interaction (Hutchins, 1996; Solomon, 1993).
- *Situated Cognition*. Knowledge often consists of resources for practical activity in the world more than of rational propositions or mental representations (Schön, 1983; Suchman, 1987; Winograd & Flores, 1986).
- *Situated Learning*. Learning is the changing participation of people in communities of practice (Lave & Wenger, 1991; Shumar & Renninger, 2002).
- *Zone of Proximal Development*. Children grow into the intellectual life of those around them; they develop in collaboration with adults or more capable peers (Vygotsky, 1930/1978).
- *Activity Theory*. Human understanding is mediated not only by physical and symbolic artifacts, but also by the social division of labor and cultural practices (Engeström, 1999; Nardi, 1996).
- *Ethnomethodology*. Human understanding, inter-personal relationships and social structures are achieved and reproduced interactionally (Dourish, 2001; Garfinkel, 1967).

One does not have to commit to one of these theories in particular in order to gain a sense from them all of the range of possible positions on the nature of group knowledge.

Common Ground or Group Cognition?

Within CSCL, it is usual to refer to the theory of "common ground" to explain how collaborative understanding is possible. Baker et al. (1999), for instance, note that collaboration requires mutual understanding among the participants, established through a process of "grounding." It is certainly clear that effective communication is generally premised on the sharing of a language, of a vast amount of practical background knowledge about how things work in the physical and social world, of many social practices implicit in interaction and of an orientation within a shared context of topics, objects, artifacts, previous interactions, etc. Much of this sharing we attribute to our socialization into a common culture or overlapping sub-cultures.

Most common ground is taken for granted as part of what it means to be human. The phenomenological hermeneutics of Heidegger (1927/1996) and Gadamer (1960/1988)—building on the traditions of Dilthey and Husserl—made explicit the ways in which human understanding and our ability to interpret meaning rely upon a shared cultural horizon. They emphasized the centrality of interpretation to human existence as being engaged in the world. They also considered cases where common ground breaks down, such as in interpreting ancient texts or translating from foreign languages—e.g., how can a modern German or American understand a theoretical term from a Platonic dialogue or from a Japanese poem?

The current discussion of common ground within CSCW and CSCL is, however, more focused. It is concerned with the short-term negotiation of common ground during interactions. Such negotiation is particularly visible when there is a breakdown of the common ground—an apparent problem in the mutual understanding. A breakdown appears through the attempt of the participants to repair the misunderstanding or lack of mutuality. For instance, in Roschelle (1996) as well as in chapters 12 and 13 much of the transcribed discourse was analyzed as attempts to reach shared understandings in situations in which the group discussion had become problematic.

It is not always clear whether repairs of breakdowns in common ground come from ideas that existed in someone's head and are then passed on to others until a consensus is established, or whether the common ground might be constructed in the interaction of the group as a whole. It is possible that shared knowledge can sometimes be best explained in one way, sometimes another. At any rate, it seems that the question of the source of shared knowledge should generally be treated as an empirical question, subject to interpretation in each concrete case. This is what is proposed in the next section of this chapter. But first, let us make this alternative a bit clearer.

The theory of common ground that Baker *et al.* (1999), Roschelle (1996) and many others in CSCL refer to is that of Clark and his colleagues. Clark & Brennan (1991) situate their work explicitly in the tradition of conversation analysis (CA), although their theory has a peculiarly mentalist flavor uncharacteristic of CA. They argue that collaboration, communication and "all collective actions are built on common ground and its accumulation" (p. 127). The process of updating this common ground on a moment-by-moment basis in conversation is called "grounding." Grounding, according to this theory, is a collective process by which participants try to reach mutual belief. It is acknowledged that understanding (i.e., mutual belief) can never be perfect (i.e., the participants can never have—and know that they have—beliefs that are completely

identical). It suffices that "the contributor and his or her partners mutually believe that the partners have understood what the contributor meant to a criterion sufficient for current purposes" (p. 129). Clark & Brennan then demonstrate how various conversational moves between pairs of people can conduct this kind of grounding and achieve a practical level of mutuality of belief. They go on to show how different technologies of computer support mediate the grounding process in different ways.

Clark's contribution theory—where one participant "contributes" a personal belief as a proposed addition to the shared common ground and then the participants interact until they all believe that they have the same understanding of the original belief, at which point their common ground is "updated" to include the new contribution—is articulated in the language of individual mental beliefs, if not to say in the jargon of computer models of rational memories. Thus, it is not surprising that Schegloff (1991b) responds polemically to Clark & Brennan by opposing the tradition of ethnomethodology and CA to this theory of mental beliefs. Schegloff points out that Garfinkel asked

> …what exactly might be intended by such notions as 'common' or 'shared' knowledge. In the days when computers were still UNIVACS, Garfinkel viewed as untenable that notion of common or shared knowledge that was more or less equal to the claim that separate memory drums had identical contents (p. 151f).

Schegloff then presented an analysis of repair in talk-in-interaction that contrasted with Clark's by construing what took place as a social practice following social patterns of interaction. According to Schegloff's approach, repair is a form of socially shared cognition that takes place in the medium of discourse (in the broad sense of social interaction-in-talk, including intonation, gesture, pose, etc.), following established conversational patterns, rather than a transfer and comparison of beliefs between rationalist minds.

In a recent critique of Clark's contribution theory of common ground, Koschmann & LeBaron (2003) present video data of an interaction in an operating room. A resident, an attending doctor and an intern are discussing the location of internal organs as viewed indirectly through a laparoscopic camera. Koschmann & LeBaron argue that the discourse that takes place does not match Clark's rubric, and that the very notion of belief contributions to some kind of common ground storage space is not useful to understanding the construction of shared understanding in this situation. Although the surgery operation is successful and although technology-supported collaborative learning takes place, the beliefs of the individual participants afterwards do not agree in Clark's sense.

Perhaps the case of the operating room illustrates Vygotsky's contrast between a person's individual developmental level and their social developmental level (separated by the zone of proximal development). The intern was able to participate in the collaborative activity even though he could not correctly identify key items on his own afterwards. This might indicate that what takes place in group interactions cannot reliably be reduced to behaviors of the individuals involved. The knowledge and abilities of people in individual and group settings are quite different. *The group cognition of the OR team* would then not be a simple sum of the individual cognitive acts of its members; the group understanding would not be a simple intersection or overlap of individual beliefs or internal mental representations. If one accepts this reading of Vygotsky's distinction

between individual cognitive ability and ability within collaborative group settings, then Clark's attempt to reduce group knowledge to individual knowledge may be misguided.

Of course, the OR situation was a special case that differed in significant ways from most everyday conversations. Often, interaction can be adequately analyzed as the exchange of personal beliefs. This is particularly true of dyadic conversations, such as those in Clark's examples, rather than in the more complex interactions of small groups of three or more in the OR or in CSCL generally. The practical question for CSCL is, can sets of students be transformed into groups that learn collaboratively in ways that encourage the emergence of collaborative group cognition in a significant sense?

Empirical Inquiry into Group Cognitive Practices

Based on the issues raised in this book, we have begun an empirical exploration of group cognition (see chapter 21). At Drexel University, we are now starting the Virtual Math Teams (VMT) Project, a research project to investigate empirically whether knowledge sharing in community contexts can construct group knowledge that exceeds the individual knowledge of the group's members. Our hypothesis is that precisely such a result is, in fact, the hallmark of collaborative learning, understood in an emphatic sense.

This research is based on earlier work that indicated the possibility of observing group cognition. As mentioned above, Roschelle's (1996) study of two students constructing a new (for them) conception of acceleration can be construed as an analysis of shared knowledge building. As Koschmann (2002b) pointed out, the analytic paradigm of that paper is ambiguous. Its focus on the problem of convergence both posits the conceptual change as taking place in the minds of the two individual students, while at the same time raising the issue of the possibility of shared knowledge. The `SimRocket` study reported in chapters 12 and 13 was an attempt to analyze knowledge building at the group level by a group of five students. Our current research project takes this earlier study as a pilot study and aims to generate a corpus of group interactions in which problem solving and knowledge building can be most effectively observed at the group level.

In the VMT project, students engage in collaborative problem solving of challenging mathematics problems. This takes place online at the Math Forum website. Students are invited into chat rooms in groups of about 4, based on similar interests, such as beginning algebra or geometry. They are given a math problem and have about an hour to discuss it. They can later submit a description of their approach to the problem to the Math Forum and receive expert feedback, but during the collaboration there is no adult mentoring.

Like many studies of collaborative learning (but unlike the VMT math study), the pilot study in chapter 12 involved face-to-face interaction with an adult mentor present. Close analysis of student utterances during a period of intense interaction during that study suggested that the group of students developed an understanding that certainly could not be attributed to the utterances of any one student. In fact, the utterances themselves were meaningless if taken in isolation from the discourse and its activity context.

There were a number of limitations to the `SimRocket` pilot study:

(1) Although the mentor was quiet for the core interaction analyzed, it might be possible to attribute something of the group knowledge to the mentor's guiding presence.

(2) The digital videotape was limited in capturing gaze and even some spoken wording.
(3) The data included only two sessions, too little to draw extensive conclusions about how much individual students understood of the group knowledge before or after the interaction.

To overcome such limitations, in our current VMT study:

(1) Mentors are not active in the collaborative groups—although the groups work on problems that have been carefully crafted to guide student inquiry, and advice can later be requested by email from Math Forum staff.
(2) The online communication is fully logged, so that researchers have a record of the complete problem-solving interaction, essentially identical to what the participants see online.
(3) Groups and individuals are studied during longer, more multi-faceted problem-solving sessions—and in some cases over multiple sessions.

Despite its limitations, the pilot study clearly suggested the feasibility of studying group knowledge. It showed how group knowledge can be constructed in discourse and how conversation analysis can "make visible" that knowledge to researchers. In the VMT project, we will analyze the interactions in the student teams to determine how they build shared knowledge within the Math Forum virtual community.

We are addressing the issue of the nature of shared understanding by studying online collaborative learning in the specific context of Math Forum problems, with the aim of presenting empirical examples of concrete situations in which groups can be seen to have knowledge that is distinct from the knowledge of the group members. By analyzing these situations in detail, we will uncover mechanisms by which understanding of mathematics passes back and forth between the group as the unit of analysis and individual group members as units of analysis.

One example might be a group of 5 middle school students collaborating online. They solve an involved algebra problem and submit a discussion of their solution to the Math Forum. By looking carefully at the computer logs of their interactions in which they collaboratively discussed, solved and reflected upon the problem, we can see that the group solution exceeds the knowledge of any individual group members before, during and sometimes even after the collaboration. For instance, there may be some arguments that arose in group interaction that none of the students fully understood but that contributed to the solution. Or a mathematical derivation might be too complicated for any of the students to keep "in mind" without reviewing preserved chat archives or using an external representation the group developed in an online whiteboard. By following the contributions of one member at a time, it may also be possible to find evidence of how each student interpreted what took place in the collaboration, and thereby to follow individual trajectories of participation in which group and individual understandings influenced each other.

While we do not anticipate that group knowledge often exceeds that of all group members under generally prevailing conditions, we hypothesize that it can do so at least occasionally under particularly favorable conditions. We believe that we can set up naturalistic conditions as part of a Math Forum service and can collect sufficient relevant data to demonstrate this phenomenon in multiple cases. The analysis and presentation of these cases should help to overcome the AM/PM paradigm conflict by providing concrete

illustrations of how knowledge can be built through group participation as distinct from—but intertwined with—individual acquisition of part of that knowledge. It should also help to clarify the theoretical framing of acts of meaning making in the context of joint activity.

Student discourse is increasingly recognized as of central importance to science and math learning (Bauersfeld, 1995; Lemke, 1990). The analysis of discourse has become a rigorous human science, going under various names: conversation analysis, interaction analysis, micro-ethnography, ethnomethodology (Garfinkel, 1967; Heritage, 1984; Jordan & Henderson, 1995; Sacks, 1992; Streeck & Mehus, 2003). This method of analysis will allow us to study what takes place through collaborative interactions.

The focus on discourse suggested a solution to the confusion between individual and group knowledge, and to the conceptual conflict about how there can be such a thing as group knowledge distinct from what is in the minds of individual group members: chapter 16 argued that meaning is constructed in the group discourse. The status of this meaning as shared by the group members is itself something that must be continually achieved in the group interaction; frequently the shared status "breaks down" and a "repair" is necessary. In the `SimRocket` pilot study, the interaction of interest centered on precisely such a repair of a breakdown in shared understanding among the discussants. While *meaning* inheres in the discourse, the individual group members must construct their own *interpretation* of that meaning in an on-going way. Clearly, there are intimate relationships between the meanings and their interpretations, including the interpretation by one member of the interpretations of other members. But it is also true that language can convey meanings that transcend the understandings of the speakers and hearers. It may be precisely through divergences among different interpretations or among various connotations of meaning that collaboration gains much of its creative power.

These are questions that we will investigate in the VMT project as part of our micro-analytic studies of collaboration data, guided by our central working hypothesis:

- H0 (collaborative learning hypothesis): A small online group of learners can—on occasion and under favorable conditions—build collaborative knowing and shared meaning that exceeds the knowledge of the group's individual members.

We believe that such an approach can maintain a focus on the ultimate potential in CSCL, rather than losing sight of the central phenomena of collaboration as a result of methods that focus exclusively on statistical trends, as argued in chapter 10.

Issues for Future Investigation

Collaborative success is hard to achieve and probably impossible to guarantee or even predict. CSCW and CSCL represent concerted attempts to overcome some of the barriers to collaborative success, like the difficulty of everyone in a group effectively participating in the development of ideas with all the other members, the complexity of keeping track of all the inter-connected contributions that have been offered, or the barriers to working with people who are geographically distant. As appealing as the introduction of technological aids for communication, computation and memory seem, they inevitably introduce new problems, changing the social interactions, tasks and physical environment. Accordingly, CSCW and CSCL study and design must take into

careful consideration the social composition of groups, the collaborative activities and the technological supports.

In order to observe effective collaboration in an authentic educational setting in the VMT project, we are adapting a successful math education service at the Math Forum to create conditions that will likely be favorable to the kind of interactions that we want to study. We must create groups by bringing together and matching up students who will work together well, both by getting along with and understanding each other and by contributing a healthy mix of different skills. We must also carefully design mathematics problems and curriculum packages that lend themselves to the development and display of deep math understanding through collaborative interactions—open-ended problems that will not be solved by one individual but that the group can chew on together in online interaction. Further, the technology that we provide to our groups must be easy to use from the start, while meeting the communicative and representational needs of the activities.

As part of our project, we will study how to accomplish these group formation, curriculum design and technology implementation requirements. This is expressed in three working hypotheses of the project: H1, H2 and H3. Two further working hypotheses define areas of knowledge building that the project itself will engage in on the basis of our findings. H4 draws conclusions about the interplay between group and individual knowledge, mediated by physical and symbolic artifacts that embody knowledge in persistent forms. H5 reports on the analytic methodology that emerges from the project:

- H1 (collaborative group hypothesis): Small groups are most effective at building knowledge if members share interests but bring to bear diverse backgrounds and perspectives.
- H2 (collaborative curriculum hypothesis): Educational activities can be designed to encourage and structure effective collaborative learning by presenting open-ended problems requiring shared deep understanding.
- H3 (collaborative technology hypothesis): Online computer support environments can be designed to facilitate effective collaborative learning that overcomes some of the limitations of face-to-face communication.
- H4 (collaborative cognition hypothesis): Members of collaborative small groups can internalize group knowledge as their own individual knowledge and they can externalize it in persistent artifacts.
- H5 (collaborative methodology hypothesis): Quantitative and qualitative analysis and interpretation of interaction logs can make visible to researchers the online learning of small groups and individuals.

We believe that the theoretical confusion surrounding the possibility and nature of group knowledge presents an enormous practical barrier to collaborative learning. Because students and teachers believe that learning is necessarily an individual matter, they find the effort at collaborative learning to be an unproductive nuisance. For researchers, too, the misunderstanding of collaborative learning distorts their conclusions, leading them to look for effects of pedagogical and technological innovation in the wrong places. If these people understood that groups can construct knowledge in ways that significantly exceed the sum of the individual contributions and that the power of group learning can feed back into individual learning, then we might start to see the real

potential of collaborative learning realized on a broader scale. This project aims to produce rigorous and persuasive empirical examples of collaborative learning to help bring about the necessary public shift in thinking.