Essays in Philosophy of Group Cognition
Gerry Stahl's Assembled Texts

- Marx and Heidegger
- Tacit and Explicit Understanding in Computer Support
- Group Cognition
- Studying Virtual Math Teams
- Translating Euclid
- Constructing Dynamic Triangles Together
- Essays in Social Philosophy
- Essays in Personalizable Software
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Essays in Philosophy of Group Cognition

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Introduction

The essays in this volume seek to address foundational questions related to the concept of group cognition. This concept emerged in the writing of my first book, *Group Cognition* (Stahl 2006a), where the theoretical themes of the present volume were already discussed, mainly in Part III, especially Chapter 16. Empirical studies of group cognition in the Virtual Math Teams (VMT) project involving problems of combinatorics were then presented in *Studying Virtual Math Teams* (Stahl 2009), where Part IV focused on conceptualizing group cognition in VMT. When the VMT project switched to dynamic geometry as its mathematical domain, *Translating Euclid* (Stahl 2013c) included Chapter 8 on theory, including both a theory of referential resources and reflections on shared understanding. Finally, *Constructing Dynamic Triangles Together* (Stahl 2015b) provided a detailed longitudinal case study oriented toward the adoption of group practices as providing preconditions for group cognition.

The present volume includes essays that attempted to address the philosophical issues raised in those broader publications. In particular, a discussion of philosophy of group cognition should tackle the following questions:

a. What is the nature of group cognition?

b. What conditions make group cognition possible?

Question (a) seeks a definition or description of group cognition: What are its characteristics and how does it differ from (or relate to) other forms of cognition, such as individual cognition and social cognition? Question (b) inquires about what the necessary preconditions are that allow for group cognition to take place, such as shared understanding among the group members.

The title of this collection is slightly awkward. It is about “philosophy of group cognition,” rather than “the philosophy” or “a philosophy.” It makes no pretentions to being the only possible analysis of its topic, nor to being a complete system. On the other hand, it does not position itself as one among many alternative philosophies. Rather, it offers a collection of conference and
journal papers or book chapters that complement each other by refining the answers to questions (a) and (b) from different perspectives and based upon excerpts of empirical student data.

Essays are not systematic presentations, but are arguments addressed to specific audiences. Each of the essays in this compilation was intended to explain the notion of group cognition to a different audience. Each was also formulated at a specific point during the trajectory of the VMT research project. By contrast, this compilation of complementary essays is not addressed to a special audience. It is for anyone interested in thinking about the foundational questions of group-cognition theory.

**Co-experiencing a Shared World**

The first essay introduces the analysis of group cognition, summarizing three doctoral dissertations on student interaction in the VMT Project. It points to the establishment within a virtual math team of a shared world as the precondition of effective group cognition. The essay was published as (Stahl, Zhou, Çakir & Sarmiento-Klapper 2011). It provides a first glimpse of the themes of this volume, grounded in case studies of student interaction in problem-solving groups.

**The Group-Cognition Paradigm**

The next essay reflects on the relationship of the research fields of CSCL and the Learning Sciences. It takes a historical view from an autobiographical engaged perspective, arguing that a new paradigm of CSCL based on group cognition can provide a theoretical basis for the learning sciences. It was published as a chapter in a volume on the history of the learning sciences, (Stahl 2016b). It sketches a context for understanding the potential centrality of group cognition within a new research paradigm.

**From Intersubjectivity to Group Cognition**

In twentieth century philosophy, the term intersubjectivity has generally raised the issue of how group cognition is possible: how can the ideas or utterances of one person be understood by other people? The journal of CSCW wanted commentaries to a lead article on “we-awareness.” This essay was submitted as one of the commentaries. It took the opportunity of this occasion to review the most important statements about intersubjectivity by philosophers and social scientists. Published as (Stahl 2016a), this may be considered the central essay of this volume.
Constituting Group Cognition

This essay, (Stahl 2014), was written for an edited book on philosophies of embodied cognition. Group cognition took its place there next to other contemporary philosophical approaches to understanding how people think and act in the world. It addressed the issue of how group cognition is constituted.

Ethnomethodology

A recent issue of the *International Journal of CSCL* published a number of articles taking—to varying degrees—ethnomethodological approaches. (Stahl 2012b) introduced the journal issue, offering an overview of ethnomethodology. Since the studies of group cognition in this volume are strongly influenced by ethnomethodology, this reflection on some theoretical positions of ethnomethodology is relevant.

Sharing Referencing

This journal article, (Stahl 2006b), related a software tool in the VMT environment—the referencing tool—to issues of group-cognition philosophy. The article had the following acknowledgement:

The Virtual Math Teams Project is a collaborative effort at Drexel University. The Principal Investigators are Gerry Stahl, Stephen Weimar and Wesley Shumar. A number of Math Forum staff work on the project, especially Stephen Weimar, Annie Fetter and Ian Underwood. The graduate research assistants are Murat Cakir, Johann Sarmiento, Ramon Toledo and Nan Zhou. Alan Zemel is the post-doc; he facilitates weekly conversation-analysis data sessions. The following visiting researchers have spent 3 to 6 months on the project: Jan-Willem Strijbos (Netherlands), Fatos Xhafa (Spain), Stefan Trausan-Matu (Romania), Martin Wessner (Germany), Elizabeth Charles (Canada), Martin Mühlpfordt (Germany). The VMT-Chat software was developed in collaboration with Martin Wessner, Martin Mühlpfordt and colleagues at the Fraunhofer Institute IPSI in Darmstadt, Germany. The VMT project is supported by grants from the NSDL, IERI and SLC Catalyst programs of the US National Science Foundation.

Common Ground

Within the CSCL research literature, the issues of intersubjectivity have often been dealt with by reference to the concept of common ground. This journal article, published as (Stahl 2005b), addresses the notion of common ground and
relates it to group cognition. The following acknowledgement was included with this article:

Parts of this essay began life within a research proposal co-authored with Stephen Weimar, Wesley Shumar and Ian Underwood of the Math Forum @ Drexel. The research project has subsequently started up. Early versions of this essay were presented at Communities & Technology 2003 in Amsterdam, Netherlands, and GROUP 2003 on Sanibel Island, Florida. Comments of JCAL reviewers helped to improve the current version.

**Productive Discourse**

The final essay in this volume was written for educators at a conference hosted by the Learning Research and Development Center (LRDC) at the University of Pittsburgh. It was subsequently published as a chapter in an edited collection: (Stahl 2015a). It may serve to tie together some of the themes and analyses that reappear throughout this volume.
Conceptualizing the Intersubjective Group

Intersubjectivity may be considered the defining characteristic of CSCL. Intersubjectivity is a concept that indicates shared understanding among people. This “sharing” is not a matter of individuals having similar understandings, but of them participating productively in a joint meaning-making discourse within a communal world. A group has achieved intersubjectivity if the members of the group interact well enough to pursue the group’s aims. Intersubjectivity must be built up gradually through interaction and repaired frequently. CSCL research explores the conditions and processes that are conducive to the establishment and maintenance of intersubjectivity among groups of learners. CSCL pedagogies promote the intersubjectively shared understanding that makes collaborative learning possible. CSCL technologies support intersubjectivity by providing media of communication and scaffolds for meaning making within a specific domain of learning.

When CSCL theories discuss “groups,” they are not referring to arbitrary gatherings of multiple learners, but to functional groups that have achieved a degree of intersubjectivity. The concept of collaborative learning in CSCL does not refer to a sum of individual learning that takes place among a group’s members, but to the increase in intersubjective understanding or knowledge building within the group that results from joint meaning making in a shared context. It involves the understanding expressed in the group discourse and the knowledge encapsulated in group products, texts or artifacts. The group’s understanding may differ from what any individual member might say, write or think when not interacting within the group.

This focus on the intersubjective group differentiates CSCL from other approaches to the study of human learning and educational instruction. It implies a research paradigm that prioritizes the group unit of analysis and studies groups that have achieved intersubjectivity. Analyzing an utterance (or chat posting) as part of a group interaction involves seeing how its meaning is constructed sequentially through its response to previous actions and elicitation
of future behavior by other group members. The meaning of the utterance is inherent in the working of that utterance within the shared world of the group, not to be explained in terms of some purported individual mental thoughts accompanying the utterance. As in Ryle’s (1968) thick description of a wink, the meaning of a wink (or utterance) is expressed by the wink itself as an interactional action, not by assumed additional intentions of the winker.

Despite the centrality of the notion of intersubjectivity to CSCL, this concept has not often been explicitly discussed in the CSCL literature. Newcomers to CSCL therefore have difficulty determining the boundaries of the field. They may assume that CSCL is the same as traditional educational psychology or instructional design, except that it involves small groups and online technology. However, the importance of analyzing intersubjectivity at the group unit of analysis has become increasingly clear to many established CSCL practitioners. For instance, the *ijCSCL* Mission Statement now specifies that the journal “features empirically grounded studies and descriptive analyses of interaction in groups, which investigate the emergence, development and use of practices, processes and mechanisms of collaborative learning.” The central research questions are no longer what experimental conditions produce the most valued learning experiences or outcomes at the individual unit, but how intersubjective meaning making and understanding is established, maintained and increased within the *interaction in groups*, by social practices, small-group processes and interactional mechanisms analyzed at the group unit.

The shift of research from assessing individual student outcomes to analyzing group-level phenomena has been slow coming and is still difficult to implement consistently. In the late 1900s, educational researchers like Johnson and Johnson (1999) or Slavin (1980) explored the effects of group interaction on learning outcomes of individual students; this was called *cooperative* learning. With the advent of CSCL, interest changed to the group processes that could be supported with networked-computer technologies. In their report on the evolution of research on *collaborative* learning, Dillenbourg, Baker, Blaye and O'Malley (1996) noted that new methods were now necessary to study group phenomena. Although Koschmann (1996b) proposed that this involved a paradigm shift, it has not been widely recognized what a radical change in perspective and methodology this shift to the group level implied.

Subsequently, Koschmann (2002a) defined CSCL in terms of “joint meaning making”—the focus of the opening article in this issue. The centrality of intersubjective meaning making to the concerns of CSCL as a research field have been stressed programmatically in scattered proposals and examples, for instance in (Arnseth & Ludvigsen 2006; Çakir, Zemel & Stahl 2009; Suthers 2006; Suthers, Dwyer, Medina & Vatrapu 2010). Multiple attempts to define new methods corresponding to this agenda of group-level analysis were also

After 20 years, CSCL researchers are just beginning to work out group-level conceptualizations, such as group cognition, group knowledge construction, group agency, group engagement, group metacognition, group practices and so on. Some researchers now see CSCL as pursuing a post-cognitive paradigm distinguished from the cognitivism of the learning sciences (Stahl 2016b). For instance, I have recently been exploring this post-cognitive paradigm through a theory of group cognition (Stahl 2014), a review of philosophical analyses of intersubjectivity (Stahl 2016a), design-based research on software support for multi-user problem solving (Stahl 2013e) and a longitudinal study of group-cognitive development (Stahl 2015b). Such a post-cognitive approach may distinguish CSCL most clearly from the methodological individualism of the educational psychology, artificial intelligence and learning sciences from which it emerged.

The current issue of *ijCSCL* provides a set of stimulating papers that illustrate and further develop a group-level focus of CSCL research. First, a discussion of Habermas’ philosophy as it relates to CSCL issues introduces to the CSCL audience the work of the contemporary author who has written the most on the concept of *intersubjectivity*. Then, three papers analyze the intersubjectivity of small groups of students in different ways. One looks at how *groups learn how to learn together* with support from specific CSCL tools. A second transforms the concept of engagement to the group unit of analysis as collaborative *group engagement*. The final one makes a parallel move for *formative feedback* and *metadiscourse*, applying them at the group level. Together, they offer stimulating glimpses of CSCL theory, technology, meta-learning and analysis focused on the group as agent.

Of course, the emphasis on group-level intersubjectivity defines just one of the paradigms active in the CSCL research community. Certainly, not all CSCL researchers identify with a post-cognitive paradigm. Perhaps the much-debated distinction between quantitative and qualitative methods should be replaced with consideration of the unit of analysis as contrasting different CSCL paradigms. CSCL has always incorporated a diversity of methodological perspectives, and *ijCSCL* has always published leading statements from all the different approaches. While this issue emphasizes studies at the group unit of analysis, future issues will continue to highlight studies of individual outcomes or community participation.
The Conditions of the Possibility of Intersubjectivity

In his introduction of Habermas’ philosophy of communicative action to the CSCL community, Michael Hammond translates from Habermas’ application of this theory in the public sphere of traditional media to the online world of CSCL. For him, Habermas is relevant because he brings a fresh, well-considered and critical perspective to the discussion of joint knowledge building. In particular, Habermas’ writings provide a framework for judging the evidence we bring to the analysis of collaborative learning as well as for valuing the evidence that our student subjects provide in their argumentation. Habermas defines the conditions necessary for the establishment of intersubjectivity, such as the inherent assumption of an ideal speech situation underlying communicative action. What Kant’s (1787/1999) *Critique of Pure Reason* did for the individual mind, articulating the conditions of the possibility of human knowledge, Habermas translated to the group level, explicating fundamental discourse conditions necessary for intersubjective meaning making in social collectivities.

Consider a student chat, a discussion forum or a medium like Wikipedia. How should we judge the quality of the knowledge building that takes place there? Moreover, how should one judge the quality of researchers’ analysis of that knowledge building? Habermas provides a standard for judgment that is grounded in the nature of human discourse. He argues that effective communication would be impossible without the underlying postulation of an ideal speech situation—even if this ideal is never in fact achievable (Habermas 1981/1984). The act of communicating with the aim of establishing intersubjectivity, making shared meaning and building knowledge together assumes that there is no other force of persuasion at work than that of the better argument and no other motivation than the cooperative search for truth. Enlightened discourse is only possible under the assumption of this goal. Of course, there always are other forces and motivations present. But the character of the ideal speech situation that underlies collaborative dialog provides a basis for critiquing those systematically distorting forces. For instance, if knowledge building assumes that no one can impose his or her views through force rather than through supported reasoning, then appeals to authority or intimidation can be soundly censured.

Habermas’ theory is, additionally, more complex and nuanced. A major contribution of his work was to distinguish realms with different criteria within the public sphere (Habermas 1967/1971). There is, as Hammond puts it, the objective world (of nature and labor), the social world (of institutions and interaction) and the subjective world (of personal experience). Each has very different criteria of validity. The objective world follows the laws of physics and
involves human mastery over nature through technical, goal-oriented, instrumental calculation; the social world, in contrast, involves normative rules reached through negotiation; while the subjective world is a matter of one’s self-narrative.

Consider the research task of analyzing an online team of students collaborating on a geometry construction. Certainly, this involves comparing the team’s work with mathematical knowledge developed in the objective world of mathematical relationships. However, it also involves tracking the development of the team’s adoption and mastery of its own group practices of collaborating and of working on geometry in the team’s social world. Furthermore, it may be possible to assess individual learning by team members as a personal-world spin-off of their teamwork. Each of these dimensions has quite different methodological criteria. Seeing how each is accomplished with the mediation of specific CSCL pedagogical approaches or CSCL technological tools can feed into design-based research for improving support for collaborative knowledge building.

Habermas’ distinction between the objective, social and subjective realms gives him leverage for his critiques of modernism and other popular philosophies, extending the critical social theory of the Frankfurt School. As cited by Hammond, Habermas’ concern with mutual recognition led him to criticize classical liberalism for reducing ethical liberty to a “possessive-individualist reading of subjective rights, misunderstood in instrumentalist terms.” There are many analogous examples in the CSCL literature, where social phenomena are inappropriately reduced either to individual subjective criteria or to instrumental objective criteria. Hammond suggests that a focus on intersubjectivity could provide a corrective in such cases and open up new perspectives for design and research. It is important to distinguish different levels of analysis carefully and to apply the appropriate evaluative criteria or analytic methods to each.

Intersubjective Learning to Learn

Teaching students to learn how to learn or to develop thinking skills has long been considered important (e.g., Looi, So, Toh & Chen 2011; Wegerif 2006)—particularly in the information age, where knowledge evolves rapidly. In their research report, Baruch B. Schwarz, Reuma de Groot, Manolis Mavrikis and Toby Dragon extend this goal to the group level with their construct of learning-to-learn-together. A core component of this approach is supporting groups of students to engage in argumentation as a form of intersubjective
meaning making. Schwarz and colleagues have previously published studies of CSCL support for argumentation in *ijCSCL* (Asterhan & Schwarz 2010; Schwarz & De Groot 2007; Schwarz & Glassner 2007; Schwarz, Schur, Pensso & Tayer 2011; Slakmon & Schwarz 2014). Now they situate computer support for argumentation in an innovative dual-interaction space.

The authors take a design-based-research approach to developing a software environment, curricular tasks and teacher roles for supporting learning-to-learn-together. They hypothesize that mutual engagement, collective reflection and peer assessment may be three critical group processes to encourage and to investigate. To explore these, they design a prototype with two primary components: a construction space and an argumentation space. The construction space includes a selection of domain-specific modeling applications to support student inquiry in specific topics of mathematics or science. This provides a mutually visible “joint problem space” (Teasley & Roschelle 1993) for collective reflection by the group on the progress of its inquiry. The software creates a shared world for mutual engagement, as opposed to individuals trying to solve a challenging problem on their own. As one group member performs an action in the space, the others assess that action in the argumentation space, either affirming it or questioning it. This prompts the students to build on each other’s actions, producing a joint accomplishment.

In some dual-interaction systems, a simple chat feature accompanies an online construction space (Lonchamp 2009; Mühlpfordt & Wessner 2009; Zemel & Koschmann 2013). This provides the possibility of engaged discourse, group reflection and peer assessment when group members are not situated face-to-face. However, the described Metafora system goes beyond this with a sophisticated planning/reflection tool. Even if the students are sitting together around a shared computer, this tool prompts, guides and supports team efforts at planning steps for the group to take (collective agency) and it facilitates team reflection on the current state (collective responsibility) (Scardamalia & Bereiter 2014). While the software mainly displays advice and ideas from the teacher or from individual students, its persistent visibility and its manipulable structure allow it to influence group agency and meta-learning. The potential power of this approach seems to come from the integration of the support for argumentation and reflection by the group with the inquiry activity itself in the shared inquiry environment. As always in CSCL, success also depends on a culture of collaboration: appropriate motivations/rewards, careful training in collaboration and subtle mentoring. The emphasis of the pedagogy and the support throughout is on the group as meta-learner.
Intersubjective Engagement

In the next presentation, Suparna Sinha, Toni Kempler Rogat, Karlyn R. Adams-Wiggins and Cindy E. Hmelo-Silver provide a multi-faceted conceptualization and operationalization of intersubjectivity based on aspects of what they term “group engagement.” Using this approach, they provide a clear illustration of a team of students that does not form an intersubjective group contrasted by one that does. The construct of group engagement developed in this paper allows the authors to identify this contrast and to analyze it using both quantitative and qualitative methods. The quantitative approach includes statistical correlations based on ratings of several aspects of group engagement, measured in five-minute intervals. The qualitative approach involves thick descriptions of illustrative excerpts of group discourse. The descriptions relate the interactions within the groups to their work (or lack thereof) of meaning making in establishing the engagement of the group as a whole in its problem-solving task.

A major achievement of the paper is to shift the analysis of engagement—which is increasingly popular in CSCL—from the psychological individual to the intersubjective group unit of analysis. The authors are explicit about this. Their observational protocol is designed to situate engagement within the collaborative group, its joint problem and its shared situation. For instance, the dimension of social engagement reflects group cohesion, or evidence that the task is conceptualized as a team effort, rather than as an individual activity. The contrast of one group’s use of the subject “we” versus the other’s use of “I” reflects in the details of the discourse the distinction documented in the ratings—showing that the distinction is actually one made by the group.

The paper is an impressive response to the cited prior research on engagement. According to the literature review, earlier studies generally operationalized engagement as consisting of a single dimension, as a stable state and as a characteristic of the individual learner. In addition, the cited work decontextualized engagement from concomitant conceptual and disciplinary tasks. By contrast, this study proposes a differentiated, evolving, multi-faceted and group-based model of engagement and applies this model to explore an insightful example from actual classroom practice. The paper’s mixed-methods analysis reflects a careful attention to the unit of analysis, operationalizing engagement at the group level. Thereby, it adds in a rich way to our conceptualization of intersubjective meaning making.
Intersubjective Metadiscourse

Like the preceding paper, the one by Monica Resendes, Marlene Scardamalia, Carl Bereiter, Bodong Chen and Cindy Halewood also uses mixed methods, with both quantitative and qualitative analysis. While collecting data at both the individual and group units of analysis, its focus is also at the group unit. In fact, it goes a step further than the previous paper and most other CSCL reports by capturing the outcomes at the group level. Here, because the main data source is a Knowledge Forum database, the group product of shared notes responding to each other within the group is the most important object for examination in response to the primary research question. Thereby, the correlation of the experimental condition with resultant collaborative learning or knowledge building can be conducted at the group level.

The social-network analysis of the Knowledge Forum notes shows the effect of experimental feedback tools on the group process and the degree of intersubjectivity established by each group. The striking visual contrast in the paper’s Figure 5 indicates that in the control condition most students are not strongly connected to other students, whereas in the experimental condition everyone is strongly connected to everyone else. Because the connections here represent sharing of vocabulary terms—such as those displayed in the experimental condition’s feedback tool—this means that there is a higher degree of intersubjective, shared understanding in the experimental groups. Shared understanding at the group unit of analysis is not dependent upon individuals’ cognitive states, internal representations, or personal understandings, but is visibly displayed in the team’s unproblematic use of shared language.

We are shown further evidence of increased group metadiscourse through the analysis of group discussion in a number of propitious interaction excerpts. While these demonstrate the experimental group’s comprehension of the visualizations of their group discourse (displays of its use of domain vocabulary and of Knowledge Forum epistemic markers), the primary metadiscourse moves (prompting the group to plan, question, analyze, explain) were made by the teacher, rather than by the student group. The experimental intervention at the group level led to productive metadiscourse, but this was not at all independent of the teacher. Thus, the study merely indicates a potential for the design of formative assessment visualizations that represent group-level behaviors and that support group metadiscourse. It does not demonstrate that the implemented tools led to student metadiscourse on their own. The students may need more experience with this approach or more maturity to take on this form of agency within the student group. Nevertheless, the paper offers stimulating design suggestions: group-level formative feedback can represent group vocabulary; support the group to evaluate its own progress; give feedback on secondary
processes (like vocabulary building, rather than directly on learning or task accomplishment); suggest positive steps (rather than just identify deficiencies); facilitate self-assessment by the group; and guide individual students to become more effective group members.

Together, the papers in this issue of *ijCSCL* suggest the centrality of intersubjectivity to a theory of CSCL and provide inspiring examples of how to explore and articulate aspects of our conceptualization of group intersubjectivity.
Seeing What We Mean: Co-experiencing a Shared Virtual World

Gerry Stahl, Nan Zhou, Murat Perit Cakir, Johann W. Sarmiento-Klapper

Abstract: The ability of people to understand each other and to work together face-to-face is grounded in their sharing of our meaningful natural and cultural world. CSCL groups—such as virtual math teams—have to co-construct their shared world with extra effort. A case study of building shared understanding online illustrates these aspects: Asking each other questions is one common way of aligning perceptions. Literally looking at the same aspect of something as someone else helps us to see what each other means. The co-constructed shared world has social and temporal as well as objective dimensions. This world grounds communicative, interpersonal, and task-related activities for online groups, making possible group cognition that exceeds the limits of the individual cognition of the group members.

The Shared World of Meaning

We all find others and ourselves within one world. We learn about and experience the many dimensions of this world together, as we mature as social beings. Infants learn to navigate physical nature in the arms of caregivers, toddlers acquire their mother tongue by speaking with others, adolescents are socialized into their cultures and adults master the artifacts of the
built environment designed by others. The world is rich with socially endowed meaning, and we perceive and experience it as immediately meaningful.

Because we share the meaningful world, we can understand each other and can work together on concerns in common. Our activities around our common concerns provide a shared structuring of our world in terms of implicit goals, interpersonal relations and temporal dimensions. These structural elements are reflected in our language: in references to artifacts, in social positioning, and in use of tenses. All of this is understood the same by us unproblematically based on our lived experience of the shared world. Of course, there are occasional misunderstandings—particularly across community boundaries—but these are exceptions, which prove the rule of shared understanding in general.

The “problem” of establishing intersubjectivity is a pseudo-problem in most cases. Human existence is fundamentally intersubjective from the start. We understand the world as a shared world and we even understand ourselves through the eyes of others and in comparison with others (Mead 1934/1962). Rationalist philosophy—from Descartes to cognitive science—has made this into a problem by focusing on the mind of the individual as if it were isolated from the world and from other people. That raises the pseudo-problem of epistemology: how can the individual mind know about states of the world and about states of other minds? Rationalist philosophy (as described by Dreyfus 1992) culminated in an information-processing view of human cognition, modeled on computer architecture: understanding is viewed as primarily consisting of a collection of mental representations (or propositions) of facts stored in a searchable memory.

Critiques of the rationalist approach (e.g., Dreyfus 1992; Schön 1983; Suchman 1987; Winograd & Flores 1986) have adopted a phenomenological (Heidegger 1927/1996; Husserl 1936/1989; Merleau-Ponty 1945/2002), hermeneutical (Gadamer 1960/1988), or ethnomethodological (Garfinkel 1967) approach, in which understanding is grounded in being-in-the-world-together, in cultural-historical traditions, and in tacit social practices. This led to post-cognitive theories, with a focus on artifacts, communities-of-practice, situated cognition, distributed cognition, group cognition, activity, and mediations by actor-networks. Human cognition is recognized to be a social product (Hegel, Marx, Vygotsky) of interaction among people, over time, within a shared world. Knowledge is no longer viewed as primarily mental representations of individuals, but includes tacit procedural knowledge (Polanyi 1966), designed artifacts (Hutchins 1996), physical representations (Latour 1992), small-group processes (Stahl 2006a), embodied habits (Bourdieu 1972/1995), linguistic meanings (Foucault 2002), activity structures (Engeström, Miettinen & Punamäki 1999), community practices (Lave 1991), and social institutions (Giddens 1984b). The critique of human thought as purely mental and individual
is now well established for embodied reality. But what happens in virtual worlds, where the physical world no longer grounds action and reflection? That is the question for this essay.

**Constructing a Shared Virtual World**

The problem of shared understanding rises again—and this time legitimately—within the context of computer-supported collaborative learning (CSCL). That is because when students gather in a CSCL online environment, they enter a virtual world, which is distinct from the world of physical co-presence. They leave the world of nature, of physical embodiment, of face-to-face perception. They enter a world that they have not all grown into together. However, this does not mean that “shared understanding” is just a matter of overlapping opinions of mental models for online groups either.

In the Virtual Math Teams (VMT) Project, we have been studying how students interact in a particular CSCL environment designed to support online discourse about mathematics. In this essay, we will illustrate some of our findings about how interaction in the VMT environment addresses the challenge of constructing a shared virtual world, in which small groups of students can productively engage in collaborative mathematics.

This essay will present a case study of Session 3 of Team C in the VMT Spring Fest 2006. Here, students aged 12-15 from different schools in the US met online for four hour-long sessions. Neither the students nor the researchers knew anything about the students other than their login user names and their behavior in the sessions. A researcher joined the students, but did not engage with them in the mathematics. Between sessions, the researchers posted feedback in the shared whiteboard of the environment. The VMT Project is described and discussed in (Stahl 2009); its theoretical motivation is presented in (Stahl 2006a). The VMT environment is shown in Figure 1. The complete chat log of Session 3 of Team C is given in the Appendix of the online version of this essay [http://GerryStahl.net/pub/cscl2011.pdf](http://GerryStahl.net/pub/cscl2011.pdf) and a Replayer version can be obtained from the authors.

In the next sections, we illustrate the following aspects of building shared understanding: (a) Asking each other questions is one common way of resolving or avoiding troubles of understanding and aligning perceptions. (b) Literally looking at the same aspect of something as someone else helps us to see what each other means. (c) The co-constructed shared world has social and temporal as well as objective dimensions. (d) This world grounds communicative, interpersonal, and task-related activities for online groups.
Questioning to Share Understanding

We have analyzed how questions posed in the VMT environment often work to initiate interactions that resolve troubles of understanding and deepen shared understanding (Zhou 2009; 2010; Zhou, Zemel & Stahl 2008). This is in contrast to the rationalist assumption that questions are requests for propositional information. We will here review a number of questions from Session 3 of Group C and indicate how they lead to shared understanding. Unfortunately, due to space limitations, we will not be able to provide the full context for these questions or a detailed conversation analysis.

The question by Qwertyuiop in Log 1 serves a coordination function, making sure that all the students have read the feedback to Session 2 before any work begins in the new Session. This is an effort, taking the form of a question, to maintain a shared experience by having everyone take this first step together.
Log 1.

<table>
<thead>
<tr>
<th>Chat Index</th>
<th>Time of Posting</th>
<th>Author</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>685</td>
<td>19:06:34</td>
<td>qwertyuiop</td>
<td>has everyone read the green text box?</td>
</tr>
<tr>
<td>686</td>
<td>19:06:44</td>
<td>Jason</td>
<td>one sec</td>
</tr>
<tr>
<td>687</td>
<td>19:06:45</td>
<td>137</td>
<td>Yes...</td>
</tr>
<tr>
<td>688</td>
<td>19:07:01</td>
<td>Jason</td>
<td>alright im done</td>
</tr>
</tbody>
</table>

Log 2.

<table>
<thead>
<tr>
<th>Chat Index</th>
<th>Time of Posting</th>
<th>Author</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>694</td>
<td>19:11:16</td>
<td>137</td>
<td>Great. Can anyone make a diagram of a bunch of triangles?</td>
</tr>
<tr>
<td>695</td>
<td>19:11:51</td>
<td>qwertyuiop</td>
<td>just a grid?</td>
</tr>
<tr>
<td>696</td>
<td>19:12:07</td>
<td>137</td>
<td>Yeah...</td>
</tr>
<tr>
<td>697</td>
<td>19:12:17</td>
<td>qwertyuiop</td>
<td>ok...</td>
</tr>
</tbody>
</table>

Log 3.

<table>
<thead>
<tr>
<th>Chat Index</th>
<th>Time of Posting</th>
<th>Author</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>698</td>
<td>19:14:09</td>
<td>nan</td>
<td>so what's up now? does everyone know what other people are doing?</td>
</tr>
<tr>
<td>699</td>
<td>19:14:25</td>
<td>137</td>
<td>Yes?</td>
</tr>
<tr>
<td>700</td>
<td>19:14:25</td>
<td>qwertyuiop</td>
<td>no-just making triangles</td>
</tr>
<tr>
<td>701</td>
<td>19:14:33</td>
<td>137</td>
<td>I think...</td>
</tr>
<tr>
<td>702</td>
<td>19:14:34</td>
<td>Jason</td>
<td>yeah</td>
</tr>
<tr>
<td>703</td>
<td>19:14:46</td>
<td>nan</td>
<td>good:-)</td>
</tr>
<tr>
<td>704</td>
<td>19:14:51</td>
<td>qwertyuiop</td>
<td>triangles are done</td>
</tr>
</tbody>
</table>

Log 2 is part of a complicated and subtle process of co-constructing shared understanding. It is analyzed in detail in (Çakir et al. 2009). The student named 137 has attempted to construct a grid of triangles in the whiteboard (similar to those in the lower left corner of Figure 1). He or she has failed (as expressed by the ironic “Great”), and has erased the attempt and solicited help by posing a question. Qwertyuiop requests clarification with another question and then proceeds to draw a grid of triangles by locating and then tweaking three series of parallel lines, following much the same procedures as 137 did. Qwertyuiop’s understanding of 137’s request is based not only on the “Yeah…” response to his/her “just a grid?” question, but also on the details of the sequentially unfolding visual presentation of 137’s failed drawing attempt.

In Log 3, the moderator, Nan, asks a question to make visible in the chat what members of the group are doing. Qwertyuiop is busy constructing the requested grid in the whiteboard and the others are presumably watching that
drawing activity and waiting for its conclusion. The students do not seem to feel that there is a problem in their understanding of each other’s activities. However, due to the nature of the virtual environment—in which the attentiveness of participants is only visible through their chat and drawing actions—Nan cannot know if everyone is engaged during this period of chat inaction. Her question makes visible to her and to the students the fact that everyone is still engaged. The questioning may come as a minor interference in their group interaction, since Nan’s questioning positions her as someone outside the group (“everyone”), exerting authority by asking for an accounting, although it is intended to increase group shared understanding (“everyone know what other people are doing”).

See What I Mean

Studies of the use of interactive whiteboards in face-to-face classrooms have shown that they can open up a “shared dynamic dialogical space” (Kershner, Mercer, Warwick & Staarman 2010) as a focal point for collective reasoning and co-construction of knowledge. Similarly, in architectural design studios, presentation technologies mediate shared ways of seeing from different perspectives (Lymer, Ivarsson & Lindwall 2009) in order to establish shared understanding among design students, their peers and their critics. Clearly, a physical whiteboard that people can gather around and gesture toward while discussing and interpreting visual and symbolic representations is different from a virtual shared whiteboard in an environment like VMT.

We have analyzed in some detail the intimate coordination of visual, narrative and symbolic activity involving the shared whiteboard in VMT sessions (Çakir 2009; Çakir, Stahl & Zemel 2010; Çakir et al. 2009). Here, we want to bring out the importance of literally looking at some mathematical object together in order to share the visual experience and to relate to—intend or “be at”—the object together. People often use the expression “I do not see what you mean” in the metaphorical sense of not understanding what someone else is saying. In this case study, we often encounter the expression used literally for not being able to visually perceive a graphical object, at least not being able to see it in the way that the speaker apparently sees it.

While empiricist philosophy refers to people taking in uninterpreted sense data much like arrays of computer pixels, post-cognitive philosophy emphasizes the phenomenon of “seeing as.” Wittgenstein notes that one sees a wire-frame drawing of a cube not as a set of lines, but as a cube oriented either one way or another (Wittgenstein 1953, sec. 177). For Heidegger, seeing things as already
meaningful is not the result of cognitive interpretation, but the precondition of being able to explicate that meaning further in interpretation (Heidegger 1927/1996, pp. 139f). For collaborative interpretation and mathematical deduction, it is clearly important that the participants see the visual mathematical objects as the same, in the same way. This seems to be an issue repeatedly in the online session we are analyzing as well.

137 proposes a mathematical task for the group in line 705 of Log 4. This is the first time that the term, “hexagonal array,” has been used. Coined in this posting, the term will become a mathematical object for the group as the discourse continues. However, at this point, it is problematic for both Qwertyuiop and Jason. In line 706, Qwertyuiop poses a question for clarification and receives an affirmative, but minimal response. Jason, unsatisfied with the response, escalates the clarification request by asking for help in seeing the diagram in the whiteboard as an “hexagonal array,” so he can see it as 137 sees it. Between Jason’s request in line 709 and acceptance in line 710, Qwertyuiop and 137 work together to add lines outlining a large hexagon in the triangular array. Demonstrating his ability to now see hexagons, Jason thereupon proceeds with the mathematical work, which he had halted in the beginning of line 709 in order to keep the group aligned. Jason tentatively proposes that every hexagon “has at least 6 triangles” and he makes this visible to everyone by pointing to an illustrative small hexagon from the chat posting, using the VMT graphical pointing tool.

Log 4.

<table>
<thead>
<tr>
<th></th>
<th>Time</th>
<th>User</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>705</td>
<td>19:15:08</td>
<td>137</td>
<td>So do you want to first calculate the number of triangles in a hexagonal array?</td>
</tr>
<tr>
<td>706</td>
<td>19:15:45</td>
<td>qwertyuiop</td>
<td>What's the shape of the array? a hexagon?</td>
</tr>
<tr>
<td>707</td>
<td>19:16:02</td>
<td>137</td>
<td>Ya.</td>
</tr>
<tr>
<td>708</td>
<td>19:16:15</td>
<td>qwertyuiop</td>
<td>ok...</td>
</tr>
<tr>
<td>709</td>
<td>19:16:41</td>
<td>Jason</td>
<td>wait-- can someone highlight the hexagonal array on the diagram? i don't really see what you mean...</td>
</tr>
<tr>
<td>710</td>
<td>19:17:30</td>
<td>Jason</td>
<td>hmm.. okay</td>
</tr>
<tr>
<td>711</td>
<td>19:17:43</td>
<td>qwertyuiop</td>
<td>oops</td>
</tr>
<tr>
<td>712</td>
<td>19:17:44</td>
<td>Jason</td>
<td>so it has at least 6 triangles?</td>
</tr>
<tr>
<td>713</td>
<td>19:17:58</td>
<td>Jason</td>
<td>in this, for instance</td>
</tr>
</tbody>
</table>

Log 5.

<table>
<thead>
<tr>
<th></th>
<th>Time</th>
<th>User</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>714</td>
<td>19:18:53</td>
<td>137</td>
<td>How do you color lines?</td>
</tr>
<tr>
<td>715</td>
<td>19:19:06</td>
<td>Jason</td>
<td>there's a little paintbrush icon up at the top</td>
</tr>
</tbody>
</table>
In Log 5, 137 asks the team to share its knowledge about how to color lines in the VMT whiteboard. Jason gives instructions for 137 to visually locate the appropriate icon in the VMT interface. Demonstrating this new knowledge, 137 changes the colors of the six lines outlining the large hexagon, from black to blue, making the outline stand out visually (see Figure 1). 137 thereby finally clarifies how to look at the array of lines as a large hexagon, a task that is more difficult than looking at the small hexagon that Jason pointed to. In this excerpt, the group shares their working knowledge of their virtual world (the software functionality embedded in it), incidentally to carrying out their task-oriented discourse within that world.

In Log 6, Jason proposes a specific mathematical task for the group to undertake, producing a formula for the number of triangles in a hexagonal array of any given side length. (As we shall see below, the group uses the term “side length” as the measure of a geometric pattern at stage n.) Qwertyuiop responds to this proposal with the suggestion to “see” the hexagon (of any size) as a configuration of six triangular areas. (To see what Qwertyuiop is suggesting, look at Figure 1; one of the six triangular areas of the large hexagonal array has its “sticks” colored with thick lines. Looking at this one triangular area, you can see in rows successively further from the center of the hexagon a sequence of one small triangle, then three small triangles, then five small triangles.)

In line 723, 137 seeks confirmation that he is sharing Qwertyuiop’s understanding of the suggestion. After posting, “Like this?” with a reference
back to Qwertyuiop’s line 722, 137 draws three red lines through the center of the large hexagon, dividing it visually into six triangular areas. Upon seeing the hexagon divided up by 137’s lines, Qwertyuiop and Jason both confirm the shared understanding. Now that they are confident that they are all seeing the mathematical situation the same, namely as a set of six triangular sub-objects, the group can continue its mathematical work. Jason draws the consequence from Qwertyuiop’s suggestion that the formula for the number of small triangles in a hexagon will simply be six times the number in one of the triangular areas of that hexagon, thereby subdividing the problem. 137 then notes that each of those triangular areas has 1+3+5 small triangles, at least for the example hexagonal array that they are looking at. The fact that the three members of the group take turns making the consecutive steps of the mathematical deduction is significant; it demonstrates that they share a common understanding of the deduction and are building their shared knowledge collaboratively.

The observation, “Each one has 1+3+5 triangles,” is a key move in deducing the sought equation. Note that 137 did not simply say that each triangular area had nine small triangles. The posting used the symbolic visual representation, “1+3+5.” This shows a pattern of the addition of consecutive odd numbers, starting with 1. This pattern is visible in the posting. It indicates that 137 is seeing the nine triangles as a pattern of consecutive odd numbers—and thereby suggests that the reader also see the nine triangles as such a pattern. This is largely a visual accomplishment of the human visual system. People automatically see collections of small numbers of objects as sets of that specific size (Lakoff & Núñez 2000). For somewhat larger sets, young children readily learn to count the number of objects. The team has constructed a graphical representation in which all the members of the team can immediately see features of their mathematical object that are helpful to their mathematical task. The team is collaborating within a shared virtual world in which they have co-constructed visual, narrative and symbolic objects in the chat and whiteboard areas. The team has achieved this shared vision by enacting practices specific to math as a profession for shaping witnessed events, such as invoking related math terms and drawing each others’ attention to relevant objects in the scene (Goodwin 1994). They have learned and taught each other how to work, discuss and perceive as a group in this shared virtual world.

**Dimensions of a Virtual World**

There has not been much written about the constitution of the intersubjective world as the background of shared understanding, particularly in the CSCL online context. This is largely the result of the dominance of the cognitive
perspective, which is primarily concerned with mental models and representations of the world; this rationalist view reduces the shared world to possible similarities of individual mental representations. Within the VMT Project, we have analyzed the dimensions of domain content, social interaction and temporal sequencing in the co-construction of a virtual math team’s world or joint problem space (Sarmiento & Stahl 2008; Sarmiento-Klapper 2009a; Sarmiento-Klapper 2009b). In this work, we have found the following conceptualizations to be suggestive and helpful: the “joint problem space” (Teasley & Roschelle 1993) and the “indexical ground of reference” of domain content (Hanks 1992); the social “positioning” of team members in discourse (Harré & Gillet 1999) and their self-coordination (Barron 2000); and the temporal sequentiality of discourse (Schegloff 1977) and the bridging of temporal discontinuities.

In its previous sessions, Team C has tried to derive formulae for the number of two-dimensional objects (small squares or small triangles) in a growing pattern of these objects, as well as the number of one-dimensional sides, edges or “sticks” needed to construct these objects. A major concern in counting the number of sides is the issue of “overlap.” In a stair-step two-dimensional pattern (like the 2-D version of the stair-step pyramid in the lower right section of Figure 1), one cannot simply multiply the number of squares by 4 to get the number of sides because many of the sides are common to two squares. In Session 1, Team C had seen that in moving from one stage to the next stage of the stair-step pattern most new squares only required two new sides.

In Log 7, Qwertyuiop moves on from the derivation of the number of triangles to that of the number of sides. He “bridges” back to the group’s earlier insight that the addition of “each polygon corresponds to [an additional] 2 sides.” In bridging to past sessions, we found, it is necessary for a group to re-situate a previous idea in the current context. In line 731, Qwertyuiop is reporting that for their hexagon formula, such situating does not work—i.e., that the current problem cannot be solved with the same method as the previous problems. The team then returns to the formula for the number of triangles and efficiently solves it by summing the sequence of consecutive odd numbers using Gauss’ technique—the sum of n consecutive odd integers is \( n(2n/2) \)—which they had used in previous sessions.

Log 7.

<table>
<thead>
<tr>
<th></th>
<th>Time</th>
<th>User</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>731</td>
<td>19:22:29</td>
<td>qwertyuiop</td>
<td>the &quot;each polygon corresponds to 2 sides&quot; thing we did last time doesn't work for triangles</td>
</tr>
<tr>
<td>732</td>
<td>19:23:17</td>
<td>137</td>
<td>It equals 1+3+...+(n+n-1) because of the &quot;rows&quot;?</td>
</tr>
<tr>
<td>733</td>
<td>19:24:00</td>
<td>qwertyuiop</td>
<td>yes- 1st row is 1, 2nd row is 3...</td>
</tr>
</tbody>
</table>
And there are \( n \) terms so...
\[ n(\frac{2n}{2}) \]
or \( n^2 \)

Jason: Yeah

Then multiply by 6

To get \( 6n^2 \)

an idea: Find the number of a certain set of colinear sides (there are 3 sets) and multiply the result by 3

As in those?

no-in one triangle. I'll draw it...

those

find those, and then multiply by 3

The green lines are all colinear. There are 3 identical sets of colinear lines in that triangle. Find the number of sides in one set, then multiply by 3 for all the other sets.

Ah. I see.

(we got a question for you from another team, which was posted in the lobby:

Quicksilver 7:44:50 PM EDT: Hey anyone from team C, our team needs to know what \( n \) was in your equations last week

The length of a side.

was \( n \) side length?

are you talking about the original problem with the squares

I think \( n \) is.

i think it's squares and diamonds

oh

then if you look in the topic description, there's a column for \( N \);

that's what it is

ok, quicksilver said they got it

so yes it is \# sides
In Log 8, Qwertyuiop makes a particularly complicated proposal, based on a way of viewing the sides in the large hexagon drawing. He tries to describe his view in chat, talking about sets of collinear sides. Jason does not respond to this proposal and 137 draws some lines to see if he is visualizing what Qwertyuiop has proposed, but he has not. Qwertyuiop has to spend a lot of time drawing a color-coded analysis of the sides as he sees them.

He has decomposed the set of sides of one triangular area into three subsets, going in the three directions of the array’s original parallel lines. He can then see that each of these subsets consists of 1+2+3 sides. There are 3 subsets in each of the 6 triangular areas. Based on this and generalizing to a growing hexagonal array, which will have sums of consecutive integers in each subset, the team can derive a formula using past techniques.

At some point, they will have to subtract a small number of sides that overlap between adjacent triangular areas. Qwertyuiop has proposed a decomposition of the hexagonal array into symmetric sets, whose constituent parts are easily visible. Thus, his approach bridges back to previous group practices, which are part of the shared world of the group—see the analysis of a similar accomplishment by Group B in (Medina, Suthers & Vatrapu 2009). The hexagonal pattern, which Team C came up with on its own, turns out to be considerably more difficult to decompose into simple patterns that the original problem given in Session 1. It strained the shared understanding of the group, requiring the use of all the major analytic tools they had co-constructed (decomposing, color-coding, visually identifying sub-patterns, summing series, eliminating overlaps, etc.).

In Log 9, the group work is interrupted by an interesting case of bridging across teams. At the end of each session, the teams had posted their findings to a wiki shared by all the participants in the VMT Spring Fest 2006. During their Session 3, Team B had looked at Team C’s work on a pattern they had invented: a diamond variation on the stair-step pattern. In their wiki posting, Team C had used their term, “side length.” Because members of Team B did not share Teams C’s understanding of this term, they were confused by the equation and discussion that Team C posted to the wiki. Team B’s question sought to establish shared understanding across the teams, to build a community-wide shared world. As it turned out, Team C had never completed work on the formula for the number of sides in a diamond pattern and Team B eventually discovered and reported the error in Team C’s wiki posting, demonstrating the importance of community-wide shared understanding.
Grounding Group Cognition

CSCL is about meaning making (Stahl, Koschmann & Suthers 2006). At its theoretical core are questions about how students collaborating online co-construct and understand meaning. In this essay, we conceptualize this issue in terms of online groups, such as virtual math teams, building a shared meaningful world in which to view and work on mathematical objects.

Log 10 illustrates a limit of shared understanding, closely related to the notion of a “zone of proximal development” (Vygotsky 1930/1978, pp. 84-91). The original stair-step pattern consisted of one-dimensional sides and two-dimensional squares. In their Session 2, Team C had generalized this pattern into a three-dimensional pyramid consisting of cubes. Now Qwertyuiop proposes to further generalize into a mathematical fourth dimension and derive formulae for patterns of one, two, three and four-dimensional objects. He had previously imported a representation of a four-dimensional hyper-cube (see the upper area of Figure 1) into the whiteboard for everyone to see.

Log 10.

<table>
<thead>
<tr>
<th>Time</th>
<th>User</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>20:12:22</td>
<td>qwertyuiop</td>
<td>what about the hypercube?</td>
</tr>
<tr>
<td>20:12:33</td>
<td>137</td>
<td>Er...</td>
</tr>
<tr>
<td>20:12:39</td>
<td>137</td>
<td>That thing confuses me.</td>
</tr>
<tr>
<td>20:13:00</td>
<td>137</td>
<td>The blue diagram, right?</td>
</tr>
<tr>
<td>20:13:13</td>
<td>qwertyuiop</td>
<td>can you imagine extending it it 4 dimensions, and a square extends into a grid?</td>
</tr>
<tr>
<td>20:13:17</td>
<td>qwertyuiop</td>
<td>yes</td>
</tr>
<tr>
<td>20:13:30</td>
<td>137</td>
<td>I didn't get that?</td>
</tr>
<tr>
<td>20:13:32</td>
<td>qwertyuiop</td>
<td>I'm having trouble doing that.</td>
</tr>
<tr>
<td>20:13:45</td>
<td>qwertyuiop</td>
<td>didn't get this?</td>
</tr>
<tr>
<td>20:15:02</td>
<td>qwertyuiop</td>
<td>If you have a square, it extends to make a grid that fills a plane. A cube fills a space. A simaller pattern of hypercubes fills a &quot;hyperspace&quot;.</td>
</tr>
<tr>
<td>20:15:19</td>
<td>137</td>
<td>The heck?</td>
</tr>
<tr>
<td>20:15:29</td>
<td>137</td>
<td>That's kinda confusing.</td>
</tr>
<tr>
<td>20:15:43</td>
<td>qwertyuiop</td>
<td>So, how many planes in a hyper cube lattice of space n?</td>
</tr>
<tr>
<td>20:16:05</td>
<td>137</td>
<td>Er...</td>
</tr>
<tr>
<td>20:16:07</td>
<td>qwertyuiop</td>
<td>instead of &quot;how many lines in a grid of length n&quot;</td>
</tr>
<tr>
<td>20:16:17</td>
<td>qwertyuiop</td>
<td>does that make any sense?</td>
</tr>
<tr>
<td>20:16:30</td>
<td>137</td>
<td>No. No offense, of course.</td>
</tr>
</tbody>
</table>
At this point late in Session 3, Jason had left the VMT environment. Qwertyuiop was unable to guide 137 to see the drawing in the whiteboard as a four-dimensional object. Apparently, Qwertyuiop had been exposed to the mathematical idea of a fourth dimension and was eager to explore it. However, 137 had not been so exposed. They did not share the necessary background for working on Qwertyuiop’s proposal. This shows that tasks for student groups, even tasks they set for themselves, need to be within a shared group zone of proximal development. The stair-step problem was in their zone—whether or not they could solve it themselves individually, they were able to solve it collectively, with enough shared understanding and background knowledge that they could successfully work together. Their three-dimensional pyramid turned out to be quite difficult for them to visualize in a shared way. Their diamond pattern seemed to be easy for them, although they forgot to work on some of it and posted an erroneous formula. The hexagonal array required them to develop their skills in a number of areas, but they eventually solved it nicely. However, the hyper-cube exceeded at least 137’s ability (or desire) to participate.

Rationalist philosophy reduces the complexity of social human existence to a logical, immaterial mind that thinks about things by representing them internally. It confuses the mind with the brain and conflates the two. It assumes that someone thinking about a hexagon or working on a math problem involving a hexagon must primarily be representing the hexagon in some kind of mental model. But one of the major discoveries of phenomenology (Husserl 1936/1989) was that intentionality is always the intentionality of some object and that cognition takes place as a “being-with” that object, not as a mental act of some transcendental ego.

As an example, we have seen that the members of Team C are focused on the graphical image of the hexagon in their virtual world on their computer screens. They reference this image and transform it with additional lines, colors and pointers. They chat about this image, not about some personal mental representations. They work to get each other to see that image in the same way that they see it. This “seeing” is to be taken quite literally. Their eyes directly perceive the image. They perceive the image in a particular way (which may change and which they may have to learn to see).

“Seeing” is not a metaphor to describe some kind of subjective mental process that is inaccessible to others, but a form of contact with the object in the world. Accordingly, we may say that shared understanding is a matter of the group members being-there-together at the graphical image in the whiteboard.

Being-there-together is a possible mode of existence of the online group. The “there” where they are is a multi-dimensional virtual world. This world was partially already there when they first logged in. It included the computer hardware and software. It included the VMT Spring Fest as an organized social
institution. As they started to interact, the students fleshed out the world, building social relationships, enacting the available technology, interpreting the task instructions and proposing steps to take together. Over time, they constructed a rich world, furnished with mathematical objects largely of their own making and supporting group practices that they had introduced individually but which they had experienced as a group.

Being-there-together in their virtual world with their shared understanding of many of this world’s features, the group was able to accomplish mathematical feats that none of them could have done alone. Each individual in the group shared an understanding of their group work at least enough to make productive contributions that reflected a grasp of what the group was doing. Their group accomplishments were achieved through group processes of visualization, discourse and deduction. They were accomplishments of group cognition, which does not refer to anything mystical, but to the achievements of group interaction. The group cognition was possible because of, and only based on, the shared understanding of the common virtual world. Shared understanding is not a matter of similar mental models, but of experiencing a shared world.

Of course, there are limits to group cognition, just as there are limits to individual cognition. We saw that Team C could not understand Qwertyuiop’s ideas about the fourth dimension. Without shared understanding about this, the group could not engage in discourse on that topic. Group cognition can exceed the limits of the individual cognition of the group members, but only by a certain amount. The individuals must be able to stretch their own existing understanding under the guidance of their peers, with the aid of physical representations, tools, concepts, scaffolds, and similar artifacts, whose use is within their grasp—within their zone of proximal development (Vygotsky 1930/1978). We have seen that Team C was able to solve a complex mathematical problem that they set for themselves involving a hexagonal array by building up gradually, systematically, and in close coordination a meaningful virtual world.

An analysis of the log of the interaction in our case study has demonstrated much about the team’s group cognition. Their group work proceeded by contributions from different individuals, with everyone contributing in important ways. Their questions showed that their individual cognition was initially inadequate to many steps in the work; but their questions also served to expand the shared understanding and to ensure that each member shared an understanding of each step. Because the students demonstrated an understanding of the group work through their successive contributions, we can see not only that individual learning took place, but we can analyze the interactional processes through which it took place through detailed analysis of their chat and drawing actions.
As Vygotsky argued, not only does group cognition lead individual cognition by several years, but individual cognition itself develops originally as a spin-off of group cognition. Individuals can learn on their own, but the cognitive and practical skills that they use to do so are generally learned through interaction with others and in small groups.

This is a powerful argument for the use of CSCL in education. It is incumbent upon CSCL research to further analyze the processes by which this takes place in the co-construction of shared understanding within co-experienced virtual worlds. As we have seen, participants in CSCL virtual environments co-construct worlds to ground their interactions. These virtual worlds exploit meaning-making, perceptual and referential practices learned in the physical social world.

Appendix

Following is the complete chat log of Session 3 of Group C of VMT Spring Fest 2006. A Replayer file of the entire Group C interaction, including whiteboard and chat is available on request from the author.

<table>
<thead>
<tr>
<th>ID</th>
<th>Time</th>
<th>Username</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>663</td>
<td>17:20:42</td>
<td>nan</td>
<td>joins the room</td>
</tr>
<tr>
<td>665</td>
<td>19:01:25</td>
<td>Jason</td>
<td>joins the room</td>
</tr>
<tr>
<td>666</td>
<td>19:02:22</td>
<td>137</td>
<td>joins the room</td>
</tr>
<tr>
<td>667</td>
<td>19:02:30</td>
<td>nan</td>
<td>hi Jason and 137, welcome back</td>
</tr>
<tr>
<td>668</td>
<td>19:02:49</td>
<td>Jason</td>
<td>hi</td>
</tr>
<tr>
<td>669</td>
<td>19:03:05</td>
<td>137</td>
<td>Hi.</td>
</tr>
<tr>
<td>670</td>
<td>19:02:56</td>
<td>nan</td>
<td>i'll be your facilitator tonight</td>
</tr>
<tr>
<td>671</td>
<td>19:02:51</td>
<td>Jason</td>
<td>it looks like ssnish is having connection problems again, even after i pointed him to an email on how to clear his Java cache</td>
</tr>
<tr>
<td>672</td>
<td>19:03:45</td>
<td>qwertyuiop</td>
<td>joins the room</td>
</tr>
<tr>
<td>673</td>
<td>19:04:07</td>
<td>nan</td>
<td>hi qwertyuiop</td>
</tr>
<tr>
<td>674</td>
<td>19:04:23</td>
<td>qwertyuiop</td>
<td>hi</td>
</tr>
<tr>
<td>675</td>
<td>19:04:24</td>
<td>nan</td>
<td>do any of you know if david is coming?</td>
</tr>
</tbody>
</table>
So we do what we did last time again?

I forgot to ask David at school.

I don't think he'd remember.

first take a few minutes to read the feedback posted on the whiteboard

no problem

I guess we can start

david can join later when he comes

Right.

has everyone read the green text box?

one sec

Yes...

Alright im done

did you see some little squares after message? I haven't seen those before, interesting

yeah, they just indicate whiteboard activity

Oh.

i see. i was on a leave for two weeks and this version is the latest

Great. Can anyone make a diagram of a bunch of triangles?

just a grid?

Yeah...

ok...

so what's up now? does everyone know what other people are doing?

Yes?

no-just making triangles

I think...

yeah

good:-)
So do you want to first calculate the number of triangles in a hexagonal array?

What's the shape of the array? a hexagon?

Ya.

wait-- can someone highlight the hexagonal array on the diagram? i don't really see what you mean...

hmm.. okay

oops

so it has at least 6 triangles?

in this, for instance

How do you color lines?

there's a little paintbrush icon up at the top

it's the fifth one from the right

Thanks.

there ya go :-)  

Er... That hexagon.

so... should we try to find a formula i guess

input: side length; output: # triangles

It might be easier to see it as the 6 smaller triangles.

Like this?

yes

yup

side length is the same...

yeah

so it'll just be x6 for # triangles in the hexagon

Each one has 1+3+5 triangles.

but then we're assuming just
<table>
<thead>
<tr>
<th>User</th>
<th>Time</th>
<th>Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>qwertyuiop</td>
<td>19:21:53</td>
<td>19:22:29 the &quot;each polygon corresponds to 2 sides&quot; thing we did last time doesn't work for triangles</td>
</tr>
<tr>
<td>qwertyuiop</td>
<td>19:22:43</td>
<td>19:23:17 It equals $1+3+...+(n+n-1)$ because of the &quot;rows&quot;?</td>
</tr>
<tr>
<td>qwertyuiop</td>
<td>19:23:43</td>
<td>19:24:00 yes- 1st row is 1, 2nd row is 3...</td>
</tr>
<tr>
<td>qwertyuiop</td>
<td>19:24:22</td>
<td>19:24:49 And there are n terms so... $n(2n/2)$</td>
</tr>
<tr>
<td>qwertyuiop</td>
<td>19:25:01</td>
<td>19:25:07 or $n^2$</td>
</tr>
<tr>
<td>Jason</td>
<td>19:25:17</td>
<td>19:25:17 yeah</td>
</tr>
<tr>
<td>Jason</td>
<td>19:25:18</td>
<td>19:25:21 then multiply by 6</td>
</tr>
<tr>
<td>Jason</td>
<td>19:25:26</td>
<td>19:25:31 To get $6n^2$</td>
</tr>
</tbody>
</table>
\(\) but this is only with regular hexagons... is it possible to have one definite formula for irregular hexagons as well |
| Jason   | 19:24:19 | 19:24:46 \(\text{(sorry to interrupt) jason, do you think you can ask ssjnish to check the email to see the instructions sent by VMT team, which might help?)}\) |
| Jason   | 19:25:42 | 19:25:48 i'm not sure if its possible tho |
\(\text{an idea: Find the number of a certain set of colinear sides (there are 3 sets) and multiply the result by 3}\) |
| Jason   | 19:25:57 | 19:26:03 i did--apparently it didn't work for him |
| Jason   | 19:26:05 | 19:26:13 or his internet could be down, as he's not even on IM right now |
| nan     | 19:26:10 | 19:26:13 i see. thanks! |
| Jason   | 19:26:20 | 19:26:36 As in those? |
| qwertyuiop | 19:26:46 | 19:27:05 no-in one triangle. i'll draw it... |
| qwertyuiop | 19:28:09 | 19:28:10 those |
| qwertyuiop | 19:28:18 | 19:28:28 find those, and then multiply by 3 |
| Jason   | 19:28:48 | 19:28:50 \(\text{The rows?}\) |
| qwertyuiop | 19:29:01 | 19:30:01 The green lines are all colinear. There are 3 identical sets of colinear lines in that triangle. Find the number of sides in one set, then multiply by 3 for all the other sets. |
Ah. I see.

Wait. Wouldn't that not work for that one?

yeah

beacuse that's irregular

Or are we still only talking regular ones?

About

side length 1 = 1, side length 2 = 3, side length 3 = 6...

Shouldn't side length 2 be fore?

*four

I count 3.

Oh. Sry.

It's this triangle.

We

I don't see the pattern yet...

We're ignoring the bottom one?

no, 3 is only for side length 2.

And I think the'ye;re all triangular numbers.

"triangular numbers"?

you mean like 1, 3, 7, ...

?

Like 1,3,6,10,15,21,28.

the sequence is 1, 3, 6...

Numbers that can be expressed as $n(n+1)/2$, where $n$ is an integer.

ah

So are we ignoring the bottom orange line for now?

"green"?

THe short orange segment.

PArallel to the blue lines.

I don't think so...

Wait, we are counting sticks right
<table>
<thead>
<tr>
<th>Time</th>
<th>Rows</th>
<th>Columns</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>19:38:35</td>
<td>19:38:48</td>
<td>qwertyuiop</td>
<td>yes—one of the colinear ets of sticks</td>
</tr>
<tr>
<td>19:38:55</td>
<td>19:39:08</td>
<td>qwertyuiop</td>
<td>oops—“sets” not “ets”</td>
</tr>
<tr>
<td>19:39:22</td>
<td>19:39:42</td>
<td>qwertyuiop</td>
<td>So we are trying to find the total number of sticks in a given regular hexagon?</td>
</tr>
<tr>
<td>19:39:50</td>
<td>19:40:18</td>
<td>qwertyuiop</td>
<td>not yet—we are finding one of the three sets, then multiplying by 3</td>
</tr>
<tr>
<td>19:40:25</td>
<td>19:40:40</td>
<td>qwertyuiop</td>
<td>that will give the number in the whole triangle</td>
</tr>
<tr>
<td>19:40:34</td>
<td>19:40:51</td>
<td>137</td>
<td>Then shouldn’t we also count the bottom line?</td>
</tr>
<tr>
<td>19:40:52</td>
<td>19:41:01</td>
<td>Jason</td>
<td>are you taking into account the fact that some of the sticks will overlap</td>
</tr>
<tr>
<td>19:41:25</td>
<td>19:41:41</td>
<td>137</td>
<td>Then number of sticks needed for the hexagon, right?</td>
</tr>
<tr>
<td>19:41:16</td>
<td>19:42:22</td>
<td>qwertyuiop</td>
<td>Yes. The blue and green/orange lines make up one of the three colinear sets of sides in the triangle. Each set is identical and doesn’t overlap with the other sets.</td>
</tr>
<tr>
<td>19:42:50</td>
<td>19:42:50</td>
<td>Jason</td>
<td>ok</td>
</tr>
<tr>
<td>19:43:03</td>
<td>19:43:11</td>
<td>Jason</td>
<td>this would be true for hexagons of any size right&gt;</td>
</tr>
<tr>
<td>19:43:09</td>
<td>19:43:13</td>
<td>qwertyuiop</td>
<td>triangle, so far</td>
</tr>
<tr>
<td>19:43:25</td>
<td>19:43:26</td>
<td>qwertyuiop</td>
<td>this one</td>
</tr>
<tr>
<td>19:43:42</td>
<td>19:43:52</td>
<td>137</td>
<td>Yes, but they will overlap...</td>
</tr>
<tr>
<td>19:43:59</td>
<td>19:44:13</td>
<td>137</td>
<td>Eventually when you multiply by 6 to get it for the whole figure.</td>
</tr>
<tr>
<td>19:44:01</td>
<td>19:44:30</td>
<td>qwertyuiop</td>
<td>no, the sets are not colinear with each other. I’ll draw it...</td>
</tr>
<tr>
<td>19:44:59</td>
<td>137</td>
<td>qwertyuiop</td>
<td>Oh. I see.</td>
</tr>
<tr>
<td>19:46:22</td>
<td>19:46:34</td>
<td>137</td>
<td>Those are the 3 sets. One is red, one is green, one is purple.</td>
</tr>
<tr>
<td>19:46:22</td>
<td>19:46:52</td>
<td>qwertyuiop</td>
<td>wait!!! I don’t see the green/purple ones</td>
</tr>
<tr>
<td>19:47:12</td>
<td>19:47:12</td>
<td>Jason</td>
<td>so we find a function for that sequence and multiply by 3</td>
</tr>
<tr>
<td>19:47:18</td>
<td>19:47:40</td>
<td>qwertyuiop</td>
<td>wait!!! I don’t see the green/purple ones</td>
</tr>
<tr>
<td>Time</td>
<td>1st Time</td>
<td>2nd Time</td>
<td>User</td>
</tr>
<tr>
<td>--------</td>
<td>----------</td>
<td>----------</td>
<td>-----------</td>
</tr>
<tr>
<td>19:48:25</td>
<td>19:48:49</td>
<td>nan</td>
<td></td>
</tr>
<tr>
<td>19:48:52</td>
<td>19:48:53</td>
<td>nan</td>
<td></td>
</tr>
<tr>
<td>19:49:04</td>
<td>19:49:04</td>
<td>Jason</td>
<td>oh</td>
</tr>
<tr>
<td>19:49:10</td>
<td>19:49:16</td>
<td>qwertyuiop</td>
<td>was n side length?</td>
</tr>
<tr>
<td>19:49:26</td>
<td>19:49:33</td>
<td>Jason</td>
<td>are you talking about the original problem with the squares</td>
</tr>
<tr>
<td>19:49:43</td>
<td>19:49:58</td>
<td>qwertyuiop</td>
<td>i think it's squares and diamonds</td>
</tr>
<tr>
<td>19:50:12</td>
<td>19:50:14</td>
<td>Jason</td>
<td>then if you look in the topic description, there is a column for N;</td>
</tr>
<tr>
<td>19:50:09</td>
<td>19:50:17</td>
<td>nan</td>
<td>ok, quicksilver said they got it</td>
</tr>
<tr>
<td>19:50:22</td>
<td>19:50:25</td>
<td>Jason</td>
<td>so yes it is # sides</td>
</tr>
<tr>
<td>19:50:21</td>
<td>19:50:26</td>
<td>nan</td>
<td>thanks guys</td>
</tr>
<tr>
<td>19:51:11</td>
<td>19:52:19</td>
<td>qwertyuiop</td>
<td>what about: f(n)=2n-1 where n is side length</td>
</tr>
<tr>
<td>19:52:55</td>
<td>19:53:03</td>
<td>137</td>
<td>I don't think that works.</td>
</tr>
<tr>
<td>19:53:07</td>
<td>19:53:18</td>
<td>137</td>
<td>How about n(n+1)/2</td>
</tr>
<tr>
<td>19:53:37</td>
<td>19:53:41</td>
<td>Jason</td>
<td>for # sticks?</td>
</tr>
<tr>
<td>19:53:38</td>
<td>19:53:48</td>
<td>qwertyuiop</td>
<td>that's number of sides for one set</td>
</tr>
<tr>
<td>19:53:50</td>
<td>19:53:51</td>
<td>qwertyuiop</td>
<td>?</td>
</tr>
<tr>
<td>19:53:57</td>
<td>19:53:59</td>
<td>Jason</td>
<td>oh ok nvm</td>
</tr>
<tr>
<td>19:54:36</td>
<td>19:54:58</td>
<td>qwertyuiop</td>
<td>then x3 is 3(n(n+1)/2)</td>
</tr>
<tr>
<td>19:55:04</td>
<td>19:55:07</td>
<td>qwertyuiop</td>
<td>simplified to...</td>
</tr>
<tr>
<td>19:55:11</td>
<td>19:55:37</td>
<td>qwertyuiop</td>
<td>(n(n+1)/1.5</td>
</tr>
<tr>
<td>19:55:34</td>
<td>19:55:44</td>
<td>137</td>
<td>On second thought, shouldn't we use n(n-1) for these:</td>
</tr>
<tr>
<td>19:55:31</td>
<td>19:55:55</td>
<td>nan</td>
<td>just a kind reminder: Jason mentioned that he needs to leave at 7p central time sharp</td>
</tr>
<tr>
<td>ID</td>
<td>Time1</td>
<td>Time2</td>
<td>User</td>
</tr>
<tr>
<td>-----</td>
<td>---------</td>
<td>---------</td>
<td>----------</td>
</tr>
<tr>
<td>831</td>
<td>19:56:05</td>
<td>19:56:19</td>
<td>nan</td>
</tr>
<tr>
<td>832</td>
<td>19:56:19</td>
<td>19:56:25</td>
<td>137</td>
</tr>
<tr>
<td>833</td>
<td>19:56:27</td>
<td>19:56:31</td>
<td>137</td>
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<tr>
<td>834</td>
<td>19:56:32</td>
<td>19:56:32</td>
<td>nan</td>
</tr>
<tr>
<td>836</td>
<td>19:56:42</td>
<td>19:56:56</td>
<td>nan</td>
</tr>
<tr>
<td>837</td>
<td>19:57:15</td>
<td>19:57:16</td>
<td>qwertyuiop</td>
</tr>
<tr>
<td>838</td>
<td>19:57:30</td>
<td>19:57:33</td>
<td>137</td>
</tr>
<tr>
<td>839</td>
<td>19:57:43</td>
<td>19:57:52</td>
<td>Jason</td>
</tr>
<tr>
<td>840</td>
<td>19:57:58</td>
<td>19:58:02</td>
<td>Jason</td>
</tr>
<tr>
<td>841</td>
<td>19:58:23</td>
<td>19:58:25</td>
<td>qwertyuiop</td>
</tr>
<tr>
<td>842</td>
<td>19:58:32</td>
<td>19:58:34</td>
<td>137</td>
</tr>
<tr>
<td>843</td>
<td>19:58:39</td>
<td>19:58:49</td>
<td>qwertyuiop</td>
</tr>
<tr>
<td>844</td>
<td>19:58:39</td>
<td>19:58:50</td>
<td>Jason</td>
</tr>
<tr>
<td>845</td>
<td>19:58:57</td>
<td>19:59:28</td>
<td>qwertyuiop</td>
</tr>
<tr>
<td>846</td>
<td>19:59:35</td>
<td>19:59:50</td>
<td>Jason</td>
</tr>
<tr>
<td>847</td>
<td>19:59:58</td>
<td>20:00:14</td>
<td>qwertyuiop</td>
</tr>
<tr>
<td>848</td>
<td>19:59:52</td>
<td>20:00:18</td>
<td>Jason</td>
</tr>
<tr>
<td>849</td>
<td>20:00:31</td>
<td>20:00:35</td>
<td>Jason</td>
</tr>
<tr>
<td>850</td>
<td>20:00:44</td>
<td>20:00:48</td>
<td>nan</td>
</tr>
<tr>
<td>851</td>
<td>20:00:53</td>
<td>20:00:57</td>
<td>nan</td>
</tr>
<tr>
<td>852</td>
<td>20:00:57</td>
<td>20:01:00</td>
<td>137</td>
</tr>
<tr>
<td>853</td>
<td>20:01:07</td>
<td>20:01:07</td>
<td>Jason</td>
</tr>
<tr>
<td>854</td>
<td>20:01:19</td>
<td>20:01:31</td>
<td>137</td>
</tr>
<tr>
<td>855</td>
<td>20:01:14</td>
<td>20:01:34</td>
<td>nan</td>
</tr>
</tbody>
</table>
Essays in Philosophy of Group Cognition

856 20:01:40 20:01:44 nan i guess that's the answer
857 20:01:47 20:01:48 nan go ahead
858 20:01:57 20:02:14 137 So then we add 12n for:
859 20:01:28 20:02:15 qwertyuiop actually, this doesn't complicate it that much. The overlaps can be accounted for with -6n
860 20:02:54 20:02:55 137 Oh.
861 20:02:56 20:03:07 137 I like addition more than subtraction.
862 20:03:11 20:03:16 qwertyuiop do you see why that works
863 20:03:18 20:03:18 qwertyuiop ?
864 20:03:12 20:03:29 137 So: 9n(n+1)-6n.
865 20:03:41 20:03:45 qwertyuiop 9, not 3?
866 20:04:13 20:04:14 137 ?
867 20:04:18 20:04:35 qwertyuiop you have "9n(n..."
868 20:04:37 20:04:47 qwertyuiop not "3n(n..."?
869 20:04:51 20:05:00 137 But we need to multiply by 6 then divide by 2
870 20:05:10 20:05:22 qwertyuiop x6 and /2 for what?
871 20:05:44 20:05:47 137 For each triangle
872 20:05:48 20:06:02 137 and /2 because it's part of the equation.
873 20:06:03 20:06:06 137 of n(n+1)/2
874 20:05:36 20:06:20 qwertyuiop it's x3 for the 3 colinear sets, then x6 for 6 triangles in a hexagon... where's the 9 and 2?
875 20:06:28 20:06:28 qwertyuiop oh
876 20:06:35 20:06:38 137 So 18/2.
877 20:06:42 20:06:50 137 A.K.A. 9
878 20:06:48 20:07:08 qwertyuiop (n(n+1)/2)x3x6
880 20:07:20 20:07:27 qwertyuiop which can be simplified...
881 20:07:42 20:07:46 137 To 9n(n+1)
882 20:08:01 20:08:04 qwertyuiop that's it?
883 20:08:10 20:08:12 137 -6n.
884 20:08:17 20:08:24 137 So 9n(n+1)-6n
<table>
<thead>
<tr>
<th>Time</th>
<th>Session Time</th>
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<tbody>
<tr>
<td>20:08:20</td>
<td>20:08:34</td>
<td>qwertyuiop</td>
<td>i'll put it with the other formulas...</td>
</tr>
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<td>20:08:39</td>
<td>20:09:47</td>
<td>qwertyuiop</td>
<td>number of triangles is...</td>
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<tr>
<td>20:10:37</td>
<td>20:10:43</td>
<td>137</td>
<td>6n^2</td>
</tr>
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<td>20:11:25</td>
<td>20:11:26</td>
<td>qwertyuiop</td>
<td>oops</td>
</tr>
<tr>
<td>20:12:12</td>
<td>20:12:22</td>
<td>qwertyuiop</td>
<td>what about the hypercube?</td>
</tr>
<tr>
<td>20:12:29</td>
<td>20:12:33</td>
<td>137</td>
<td>Er...</td>
</tr>
<tr>
<td>20:12:36</td>
<td>20:12:39</td>
<td>137</td>
<td>That thing confuses me.</td>
</tr>
<tr>
<td>20:12:56</td>
<td>20:13:00</td>
<td>137</td>
<td>The blue diagram, right?</td>
</tr>
<tr>
<td>20:12:37</td>
<td>20:13:13</td>
<td>qwertyuiop</td>
<td>can you imagine extending it it 4 dimensions, and a square extends into a grid?</td>
</tr>
<tr>
<td>20:13:26</td>
<td>20:13:30</td>
<td>137</td>
<td>I didn't get that?</td>
</tr>
<tr>
<td>20:13:41</td>
<td>20:13:45</td>
<td>qwertyuiop</td>
<td>didn't get this?</td>
</tr>
<tr>
<td>20:13:57</td>
<td>20:15:02</td>
<td>qwertyuiop</td>
<td>If you have a square, it extends to make a grid that fills a plane. A cube fills a space. A simaller pattern of hypercubes fills a “hyperspace”.</td>
</tr>
<tr>
<td>20:15:17</td>
<td>20:15:19</td>
<td>137</td>
<td>The heck?</td>
</tr>
<tr>
<td>20:15:16</td>
<td>20:15:43</td>
<td>qwertyuiop</td>
<td>So, how many planes in a hyper cube latice of space n?</td>
</tr>
<tr>
<td>20:16:04</td>
<td>20:16:05</td>
<td>137</td>
<td>Er...</td>
</tr>
<tr>
<td>20:15:48</td>
<td>20:16:07</td>
<td>qwertyuiop</td>
<td>instead of &quot;how many lines in a grid of length n&quot;</td>
</tr>
<tr>
<td>20:16:11</td>
<td>20:16:17</td>
<td>qwertyuiop</td>
<td>does that make any sense?</td>
</tr>
<tr>
<td>20:16:23</td>
<td>20:16:30</td>
<td>137</td>
<td>No. No offense, of course.</td>
</tr>
<tr>
<td>20:16:35</td>
<td>20:16:43</td>
<td>qwertyuiop</td>
<td>ok... let me think...</td>
</tr>
<tr>
<td>20:17:29</td>
<td>20:17:31</td>
<td>137</td>
<td>Right.</td>
</tr>
<tr>
<td>20:17:23</td>
<td>20:18:07</td>
<td>qwertyuiop</td>
<td>The squares are 2 dimensional and they can be arranged in a grid to tessulate over a plane. The plane is also 2 dimensional.</td>
</tr>
</tbody>
</table>
If you use 3 dimensional cubes, they can be arranged to fill a 3 dimensional space.

If you have hypercubes, they can be arranged to fill a 4 dimensional "hyperspace"

you may want to make your ideas available on the wiki before you go

which may take some time

Actually, I only have around 10 minutes left.

you say "and that structure's 4 dimensional?" -what's "that"

I have homework to do, too...

So how the heck are we supposed to calculate the number of four-dimensional figures?

do you want to stop here and start putting ideas on wiki?

ok

Sure.

resume from here next time?

sure

Ya.

We have the 2 hexagon equations to put on the wiki.

Right.

Where's the wiki again?

open "view topic"
<table>
<thead>
<tr>
<th>Time</th>
<th>User</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>20:23:31</td>
<td>137</td>
<td>Somewhere in the View topic button</td>
</tr>
<tr>
<td>20:23:41</td>
<td>nan</td>
<td>there's link</td>
</tr>
<tr>
<td>20:23:54</td>
<td>qwertyuiop</td>
<td>I see it.</td>
</tr>
<tr>
<td>20:24:28</td>
<td>137</td>
<td>leaves the room</td>
</tr>
<tr>
<td>20:25:02</td>
<td>qwertyuiop</td>
<td>i'll write it.</td>
</tr>
<tr>
<td>20:25:05</td>
<td>qwertyuiop</td>
<td>leaves the room</td>
</tr>
<tr>
<td>20:25:19</td>
<td>nan</td>
<td>leaves the room</td>
</tr>
</tbody>
</table>
The Group as Paradigmatic Unit of Analysis: The Contested Relationship of CSCL to the Learning Sciences

This essay looks at the relationship of two historically and institutionally related research communities: Computer-Supported Collaborative Learning (CSCL) and the Learning Sciences (LS). It presents them from the perspective of the author as a participant in those communities during the past 20 years (1995-2015). It reviews the institutional history of their relationship within the International Society of the Learning Sciences (ISLS). The question is then posed: Do CSCL or LS represent a new paradigm of educational research? Trends in the history of philosophy and social theory are reviewed to motivate a contemporary paradigm. A post-cognitive educational paradigm is proposed that focuses on group interaction as the unit of analysis. Finally, the author’s CSCL research agenda is described as an illustration of a candidate approach. In conclusion, it is proposed that CSCL research should focus on the analysis of group processes and practices, and that the analysis at this level should be considered foundational for LS.

A Participant’s View of LS and CSCL

LS and CSCL are not easy to clearly distinguish. There are no objective or fixed definitions of these two fields. They are best understood as communities of researchers. Despite their fluidity, they do seem to evolve over time. The shifting nature of the communities appears differently to different participants and is often negotiated in discussions among them. In this essay, I discuss the
relationship between the CSCL and LS communities from the perspective of my own participation in them.

CSCL is trans-disciplinary, requiring a mix of academic backgrounds. I came to CSCL from philosophy and computer science. In the 1960s and early 1970s, I studied twentieth-century continental philosophy and social theory at MIT, Northwestern, Heidelberg and Frankfurt, but supported myself as a math teacher and computer programmer. In the early 1990s, I studied computer science academically, specializing in AI, design theory, HCI and CSCW at the University of Colorado in Boulder. Upon graduation in 1993, I decided to apply computer science to educational innovation. When Timothy Koschmann spent a year at Boulder during 1997/98 while I was starting my career as a research professor, I participated in his course on CSCL and he introduced me to local conversation analysts, whose courses I also attended. Koschmann was instrumental in organizing the first seven CSCL conferences and editing the seminal CSCL book (Koschmann 1996a). I participated in all the CSCL conferences, starting in 1995, and also the ICLS conferences from 1998 on. During 2001/02, I lived in Germany for a year and worked on a European Union CSCL research project. That year, I met many of the Europeans active in the CSCL community and visited their labs, workshops and conferences.

Koschmann convinced me to be program chair of CSCL 2002 in Boulder. At the closing session of CSCL 2002, those present agreed to found a new organization, the International Society of the Learning Sciences (ISLS), to provide an institutional framework to bring together the CSCL and ICLS conference series and also the Journal of the Learning Sciences (JLS). It was decided that Timothy Koschmann, Janet Kolodner and Christopher Hoadley would share leadership of the society. I agreed to be on the founding board, to draft the by-laws, to set up the website and to design a logo.

The contested relationship of CSCL to LS soon flared up at CSCL 2003 in Bergen, when the legal incorporation of ISLS was announced there. The central participants in the CSCL community were largely European members of the AI-in-Education community. They felt that Roger Shank had betrayed the AI-in-Education community when he hosted their conference at Northwestern in 1991 and used that occasion to proclaim himself the leader of a new field, which he called “the learning sciences.” Kolodner was seen as his protégée, who had extended his technical contribution in AI models of case-based reasoning and was the founding editor of JLS, the journal of LS. At the time, virtually all articles in JLS had been by North American authors and represented a strongly cognitivist approach. ICLS, the conference series for LS, was held exclusively in the US until 2008, and had been dominated by a few American schools, primarily departments of education at elite US universities (e.g., Northwestern,
So at the Bergen conference, a group of European CSCL researchers raised harsh questions about whether ISLS was an attempt by American LS leaders to take over the field of CSCL and its conference series, which was finally being held in Europe in 2003—after Euro-CSCL 2001 in Maastricht was retroactively recognized as an official CSCL conference. Kolodner, Koschmann and Hoadley were unable to satisfy the concerns raised. There was lively discussion among the conference attendees, and a smaller group of us drafted a position paper overnight. The outcome was to proceed with the establishment of ISLS, but to set up a CSCL Committee within ISLS to represent the CSCL community. The CSCL Committee would exercise control over CSCL matters, like the CSCL conference series. During the same conference, the idea of a CSCL journal was proposed; Hans Spada suggested that I found it with the co-editorship of Friedrich Hesse. Pierre Dillenbourg had already established a CSCL book series published by Springer. These initiatives helped to form links and establish parity between LS and CSCL.

ISLS gradually became established. Hoadley was the first President, and subsequent presidents included several prominent European and American CSCL researchers, including some who had raised the original critical questions at the 2003 Bergen conference. Kolodner served as Executive Director of ISLS throughout its formative years. The tension between CSCL and LS gradually dissipated; the CSCL Committee lingered on, primarily playing a symbolic role. ISLS, ICLS and JLS gradually made concerted efforts to become more international and to broaden their leadership. Although the assumption has generally been that the two communities have largely merged, my sense is that the theoretical differences between them and between the two conference series have not much altered during the intervening decade.

It is hard to define the difference between CSCL and LS other than, perhaps, in terms of the people involved. This is because both communities profess openness to the same range of theoretical and methodological frameworks, although both promote certain preferred orientations in subtle and unspoken ways. For instance, most researchers in both fields claim to accept the situated nature of learning and the sociocultural perspective, but if you look closely at their analyses, you find that they rely on methods and approaches that predate and may contradict these positions. (More on this assertion to come.)
Did CSCL or LS Adopt a New Paradigm?

In the introduction to his edited volume of CSCL studies, Koschmann (1996a) proclaimed that CSCL provided a new paradigm of research on instructional technology. He used Kuhn’s principle that a paradigm must be “sufficiently unprecedented to attract an enduring group of adherents away from competing modes of scientific activity” (Kuhn 1972, p. 10). A few years later, as Koschmann saw that there was no consistency in method among CSCL studies and that the vast majority of CSCL and LS studies had, in fact, not moved away from traditional approaches to measuring individuals’ learning outcomes, he reconsidered that claim. He argued that:

Traditional theories of learning treat learning as a concealed and inferred process, something that “takes place inside the learner and only inside the learner” (Simon 2001, p. 210). CSCL research has the advantage of studying learning in settings in which learning is observably and accountably embedded in collaborative activity. Our concern, therefore, is with the unfolding process of meaning making within these settings, not so-called “learning outcomes.” It is in this way that CSCL research represents a distinctive paradigm within IT. By this standard, a study that attempted to explicate how learners jointly accomplished some form of new learning would be a case of CSCL research, even if they were working in a setting that did not involve technological augmentation. On the other hand, a study that measured the effects of introducing some sort of CSCL application on learning (defined in traditional ways) would not. (Koschmann 2001, p. 19)

In his keynote talk at CSCL 2002, Koschmann proposed that “CSCL is a field of study centrally concerned with meaning and the practices of meaning making in the context of joint activity, and the ways in which these practices are mediated through designed artifacts” (Koschmann 2002a, p.17). He then reviewed what he took to be a seminal CSCL paper by Jeremy Roschelle (1992) as an early instance of the CSCL paradigm, because Roschelle focused on the analysis of meaning-making practices (such as conversational moves) in a context of joint activity (dyads working on challenges) mediated by a designed activity (a software simulation).

Koschmann focused on the version that Roschelle published in JLS—which Koschmann himself later republished in his CSCL edited volume (Roschelle 1996). However, in terms of the relationship of CSCL and LS, the situation was rather more complicated as well as more interesting than what Koschmann reported. First, Teasley and Roschelle (1993) presented an analysis involving the co-construction of a “joint problem space” (JPS) by students,
Essays in Philosophy of Group Cognition

using Roschelle’s dissertation data. The JPS was an explicit transformation of the cognitivist conception of a mental problem space in (Newell & Simon 1972) into the intersubjective realm of situated interaction. Newell and Simon’s notion of cognitive production rules (mental mechanisms) was re-conceptualized as socially distributed, turn-taking, collaborative completions (discourse moves).

Stephanie Teasley was instrumental in bringing a post-cognitive framework to this analysis in her collaboration with Roschelle, while they were both interns at the Institute for Research on Learning (IRL) in Palo Alto. IRL was a hotbed of post-cognitive innovation, inspired by theories of conversation analysis, ethnomethodology, activity theory, situated action and situated learning. Teasley (then named Behrend) and Roschelle first presented their analysis with co-author Janice Singer at the CSCW 88 and ITS 88 conferences (Behrend, Singer & Roschelle 1988; Singer, Behrend & Roschelle 1988). These papers grew into the version later published as (Teasley & Roschelle 1993), presented at a NATO-sponsored workshop in Italy in 1989 (the first event ever to use the term “CSCL”).

It was these early versions that really emphasized the intersubjective practices of meaning making in the context of joint activity. The authors explicitly juxtaposed their perspective to cognitivism: “Thus, in contrast to traditional cognitive psychology, we argue that collaborative problem solving takes place in a negotiated and shared conceptual space, constructed through the external mediational framework of shared language, situation and activity—not merely inside the cognitive contents of each individual's head” (Roschelle & Teasley 1995, p. 70).

In the JLS article reporting on this research, Roschelle argues that the ability of the dyad to “share” knowledge in a cognitive sense (as convergent mental contents) could be demonstrated by an analysis of the collaborative sense in which the students “share” a joint meaningful world (are engaged with co-constructed meanings and artifacts). Tying the analysis of intersubjective meaning making to the problematic of cognitive convergence had the potential of appealing to the JLS audience, because it put the argument in cognitive terms they could relate to without disrupting their paradigm. However, this made the argument more complex and probably detracted from its ability to stand as a clear example of a post-cognitive paradigm.

Koschmann concluded that CSCL could be a new paradigm if studies would maintain a focus on how groups of learners collaboratively achieve new understandings in the presence of computational artifacts. However, in most CSCL studies (as in LS studies) there is a conflict between the espoused and the applied theory of learning or between the motivating theoretical concerns and the bottom-line methods of analysis. After Roschelle and Teasley’s publications, most actual instances of research by the CSCL (or LS) community fall back on
old traditions in educational psychology or other forms of measuring and correlating learning outcomes of individuals—sometimes despite the researchers’ best intentions and the needs of their research questions.

Measuring the effectiveness of dialog or collaboration is never a straightforward affair. It is highly dependent upon the details of the setting and the group practices. Methodological concerns related to this were expressed early in the history of CSCL, for instance by Dillenbourg et al. (1996, p. 189):

For many years, theories of collaborative learning tended to focus on how individuals function in a group. More recently, the focus has shifted so that the group itself has become the unit of analysis. In terms of empirical research, the initial goal was to establish whether and under what circumstances collaborative learning was more effective than learning alone. Researchers controlled several independent variables (size of the group, composition of the group, nature of the task, communication media, and so on). However, these variables interacted with one another in a way that made it almost impossible to establish causal links between the conditions and the effects of collaboration. Hence, empirical studies have more recently started to focus less on establishing parameters for effective collaboration and more on trying to understand the role that such variables play in mediating interaction. In this essay, we argue that this shift to a more process-oriented account requires new tools for analyzing and modeling interactions. (Italics added)

In the first volume of the International Journal of CSCL (ijCSCL), Suthers (2006, p. 321) proposed a research agenda for CSCL: “To study the accomplishment (a post hoc judgment) of intersubjective learning we must necessarily study the practices (the activity itself) of intersubjective meaning making: how people in groups make sense of situations and of each other.” He agreed on the need for CSCL research to focus on analysis of group processes. He immediately noted, however, that few studies published in the CSCL literature have addressed intersubjective meaning making directly.

There are many pressures against research adopting a new paradigm and new tools for analyzing interactions. For one, the study of interaction processes and group practices requires analytic skills that are not generally taught in standard college courses on research methods and statistics. There are also external influences: The public wants stories that meet common-sense images of science based on popular notions of traditional science, primarily Newtonian physics. Politicians and funding sources want simple numeric results that they can cite as clear measures of return on government or grant investments in education. Academic hiring and promotion committees want publications in well-established conferences and journals to justify their decisions. Conferences
and journals rely on peer review by scholars trained in traditional notions of rigor. Systems of social rewards—which largely define behaviors in academic research communities—militate against methodological innovation, even as they reward superficial adherence to the latest trends.

It is hard to determine how many publications in CSCL or LS break free of the cognitivist paradigm’s stronghold on publication. For instance, studies of CSCL publications bring their own paradigmatic blinders or filters (e.g., Akkerman et al. 2007; Jeong & Hmelo-Silver 2010; Jeong, Hmelo-Silver & Yu 2014; Kienle & Wessner 2006; Lonchamp 2012; Tang 2014). They sometimes eliminate from consideration any paper that does not focus on “empirical” data analysis, often excluding ethnographic case studies and certainly theoretical articles. They generally miss many of the most influential papers or more innovative approaches. Many highly rated journals in the educational field advertise that they only publish papers that conform to traditional empiricist methodological standards. The stances of these journals in turn influence the attitudes of reviewers for other journals and conferences. Attempts to categorize publications in CSCL and LS often succumb to a similar fate, imposing implicit or explicit criteria on the selection of papers to be categorized.

We have seen that it is hard to determine the extent to which a post-cognitive paradigm is making headroads in CSCL and/or LS research. What would a CSCL paradigm look like that systematically thematized the mutual engagement of small groups in meaning making and problem solving, as suggested by Koschmann; Roschelle and Teasley; Suthers; Dillenbourg, Baker, Blaye and O’Malley? The following sections explore the implications of the post-cognitive theories that are so often espoused within the CSCL and LS communities, but relatively rarely carried through in the published analyses. They trace these recent theories back to their roots in the history of philosophy, noting the historic junctures that provide the ontological and epistemological motivations for various alternative methodologies. They conclude by recommending that a CSCL focus on group cognition be taken as foundational for LS.

The Post-cognitive Philosophical Paradigm

The post-cognitive CSCL paradigm studies *meaning making as a joint (or group) activity*. For instance, the analysis by (Teasley & Roschelle 1993) in terms of the collaborative activity of constructing a joint problem space was an early instance of this new paradigm. However, the analysis of the same data in terms of cognitive convergence reduced the meaning making to measures of traditional
individual mental phenomena—externally influenced by computer images and internally involving corresponding mental representations of those images in the heads of the students.

Figure 1. The evolution from individualistic to social theories in philosophy and social science. A major paradigm shift in theory occurred two centuries ago, but has still not affected most CSCL and LS analyses.

To grasp the significance of this distinction between cognitive and post-cognitive, consider the schematic history in Figure 1 of a strand within Western philosophy and social theory that contributed to the theoretical foundation of this paradigm shift.

Philosophy began with the classic Greeks locating knowledge in eternal ideas, rather than in the social norms of the polis or the traditions of mythology. Descartes relocated these ideas in the individual mind, and thereby created the epistemological problem: how can ideas in the mind correspond to valid knowledge of the non-mental world? Locke and Hume gave opposing views in response to Descartes, emphasizing individual human reason or individual human experience. Various mixtures of these philosophies motivated scientific paradigms of rationalism, empiricism, positivism and behaviorism. Kant overcame the conflict between rationalism and empiricism by arguing that the human mind constructs what it can know of the world by structuring sense perception with categories of space, time and causality. Thus, Kant provided the
philosophic basis for the paradigms of constructivism and cognitivism: People construct knowledge, so an analysis of human behavior and learning must take into account the role of cognition in making sense of the world.

Note that up to this point, human nature and human cognition were posited as based in the individual person, as fully determined from birth ahistorically or universally—not dependent on one’s biography or social context. Remember that the views that minds develop (Freud), that social relations transform (Marx) or that humanity evolves (Darwin) all came after Hegel—inspired by his dynamic philosophy. The outmoded pre-Hegelian, ahistorical view survives in our culture as common sense and as a pervasive ideology of individualism. It also survives in the empiricist and rationalist assumptions about science, which persist in positivist notions of objectivity and reductionism to individual cognition.

Hegel (1807/1967) argues that human consciousness emerges through productive activity in the social and physical world: Individuals are formed as such (i.e., as self-conscious individuals) through the interaction with each other and with artifacts (tools and products of work) in the world. Hegel describes the emergence of self-consciousness from within the process of mutual recognition of self and other.

Marx (1867/1976) builds on this analysis of social interaction. He situates Hegel’s idealist analysis in the historical context of capitalism. For Marx, individuals in capitalist society are analyzed as results of their interactions as wage laborers, owners of the means of production or consumers of commodities. The “cell form” of social analysis is the interaction between worker and owner that produces artifacts for the market. Marx critiques the traditional notion of the abstract individual as an ideology that obscures concrete human reality as fundamentally social.

In the cognitive paradigm, one assumes that an interaction such as takes place in a CSCL setting can be analyzed in terms of individuals, who can be characterized independently of the interaction context, for instance by characterizing their mental states and internally stored knowledge. The sense making that takes place is attributed to the individuals, who then may compare their understandings. By contrast, in the post-cognitive theories listed across the bottom of Figure 1, interaction is primary. For instance, Linell (2009) describes his post-cognitive dialogical approach:

In the analysis of sense-making as it occurs in communication and interventions into the world, as well as in solo thinking or the reading of texts, etc., we must start out from the encounters, interactions, events etc. as the basic phenomena; they are primary, not secondary or derived. This idea makes dialogism different from mainstream
psychology, which is based on the assumption—self-evident for its adherents—that individuals are there first, and then they sometimes interact with other individuals. Interaction for them is “external,” that is, of a secondary nature. Dialogists, by contrast, assume that individuals have become what they are in and through interaction.

Toward a Post-cognitive Educational Paradigm

An interrelated set of attempts to propose approaches to education, sociology and psychology embody new paradigms of research in keeping with the post-cognitive philosophical paradigm. Some of them are included in Figure 1. They focus methodologically on group interaction and study dynamic processes rather than just outcomes. Most of them are inspired by Vygotsky or, more generally by Marx, Heidegger and Wittgenstein. They include Bruner (1990), Cole (1996), Engeström (1987), Garfinkel (1967) and their colleagues or followers, each of whom emphasizes different aspects of the paradigm.

Vygotsky adopts Marx’s ontology: the primary unit of analysis is the interaction among people mediated by artifacts. Artifacts are both physically present in the world and meaningful to people. Vygotsky’s notion of artifact includes both tools and language. Their meaning is not projected from individual minds, but is intersubjectively emergent from social interactions, as in the dialectical analyses of Hegel and Marx. Consider Vygotsky’s programmatic attempt to show how the individual mind is grounded in activity within the physical and social world. His description of the genesis of the pointing gesture illustrates a typical early experience of meaning for a small child; it shows how the meaning of this artifact is created in the intersubjective world and only subsequently incorporated (internalized) in the child’s own sense-making repertoire:

We call the internal reconstruction of an external operation internalization. A good example of this process may be found in the development of pointing. Initially, this gesture is nothing more than an unsuccessful attempt to grasp something, a movement aimed at a certain object, which designates forthcoming activity…. When the mother comes to the child’s aid and realizes this movement indicates something, the situation changes fundamentally. Pointing becomes a gesture for others. The child’s unsuccessful attempt engenders a reaction not from the object he seeks but from another person. Consequently, the primary meaning of that unsuccessful grasping movement is established by others…. The grasping movement changes to
the act of pointing. As a result of this change, the movement itself is then physically simplified, and what results is the form of pointing that we may call a true gesture. (Vygotsky 1930/1978, p. 56, italics added)

Here we see the genesis of the meaning of a pointing gesture. The recognized, practical and formalized gesture becomes an artifact: it embodies meaning in the physical world. The meaning is a reference to that which is pointed at. The baby intended some object; the mother recognized that the baby intended that object; the baby recognized that the mother recognized this. The multiple mutual recognition entails that the baby and the mother recognize each other as people who can have intentions and who can recognize intentions of other people. This is a first glimmer of self-consciousness, in which the baby becomes conscious of his own and other people’s intentionality. (Of course, the baby cannot yet express this self-consciousness in any verbal or conceptual sense, but only behaviorally.) The key point for us here is not the birth of intentionality, social recognition or self-consciousness. It is the analysis of an artifact, such as the pointing gesture, a ubiquitous form of reference or deixis. In the origin of this gesture, we already see the basis for intersubjective, shared understanding of an artifact’s meaning. The subsequent usage of this pointing gesture is premised upon the mutual recognition of an underlying intention, which emerged within the mother-child interaction.

The view of shared intention as co-constructed in the world stands in sharp contrast to the rationalist assumption that individuals first have intentions—as though produced by logical calculations of self-interest by a homunculus in their heads—which they subsequently express in speech or action. Marx, Wittgenstein and Heidegger—and their successors—soundly reject this cognitive assumption (see, e.g., Dennett 1991; Dreyfus 1992; Suchman 2007). Heidegger (1927/1996), for instance, replaces Descartes’ dichotomy of mental and physical with a philosophy of human being-there-together-in-the-world. Ones comportment in the world precedes ones reflection upon objects in the world. People understand the shared world through their involvement with and their care for the world with other people who also inhabit that world, not initially through mental representations and plans. Human involvement is fundamentally processual or temporal: we aim at our projects for the future, based on having been thrown by our social past, into our shared situation in the present.

In their seminal post-cognitive analysis of agency, drawing on contemporary philosophy and social science, Emirbayer and Mische (1998p. 962) conceptualize agency in Heideggerian temporal terms. Applied to the group unit of analysis as “group agency,” their post-cognitive concept could inform CSCL analysis (as in Charles & Shumar 2009; Damsa 2014). It is important to reconsider the notion of agency (and causality)—as Latour (1990; 1992) does by extending it to other people and artifacts in actor networks. The traditional
conception of agency contributes to the difficulty of overcoming cognitive habits of thought. A post-cognitive paradigm could include group cognition, collective intentionality and group agency.

The Need for a Post-cognitive CSCL Paradigm

A paradigm shift can be motivated by anomalies in the established theories (Kuhn 1972; Lakatos 1976). Consider anomalies in the paradigm of measuring learning outcomes: from the research of Vygotsky and from CSCL research.

In Vygotsky’s well known discussion of the “zone of proximal development,” he cites a study in which children “could do only under guidance, in collaboration and in groups at the age of three-to-five years what they could do independently when they reached the age of five-to-seven years” (1930/1978, pp. 86f). CSCL can be seen precisely as such an effort to stimulate students within their zones of proximal development under guidance, in collaboration and in groups. If the desired results of this do not show up as learning outcomes measurable in individuals (outside of their group context) for several years, then the key effect will be systematically missed by traditional methods of testing individuals. The failure of the cognitive paradigm of instructional research to account for processes in the zone of proximal development—so central to learning—should be considered an anomaly, suggesting the need for a paradigm shift.

In his less quoted section on “Problems of Method,” Vygotsky (1930/1978pp. 58-75) called for a new paradigm of educational research almost a century ago. Arguing that one cannot simply look at visible post-test results of an experiment, he proposed a method of “double stimulation” where a child is confronted by both an object to work on and an artifact to mediate that work. Vygotsky does not call for a controlled experiment that compares learning outcomes with and without the furnished artifact. “The experiment is equally valid,” he points out, “if, instead of giving the children artificial means, the experimenter waits until they spontaneously apply some new auxiliary method or symbol that they then incorporate into their operations.” Taking this approach in a collaborative setting requires an attention to the children’s interaction and the sense making that is involved in creative, unanticipated collaborative accomplishments. It involves understanding the unique trajectories of different groups, which cannot be statistically aggregated or sorted into standardized categories.

Relatedly, a number of CSCL studies have repeatedly documented “productive failure” (Barron 2003; Kapur & Kinzer 2009; Pathak, Kim,
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Jacobson & Zhang 2011; Schwartz 1995). This is one of the most intriguing findings of CSCL to date. However, it has so far been analyzed in terms of learning outcomes, rather than group practices within zones of proximal development. When a number of small groups of students work on a challenging problem, the groups sometimes fall into two categories: (a) Groups that fail to solve the immediate problem but excel at solving future related problems. (b) Groups that succeed at solving the immediate problem but are less successful than the first groups at solving subsequent related problems. The robust and repeatable result of these experiments presents an anomaly for traditional educational theory. One could speculate that in the “failure” groups students are further developing their zone of proximal development or that these groups are co-constructing helpful new meanings, whereas the groups that solve the immediate problems are focused on efficiently applying their existing skills. The analysis of group processes effecting outcomes this way requires a post-cognitive perspective.

A CSCL Researcher’s Agenda

As an example of a CSCL research project conducted in a post-cognitive paradigm, I describe my own work during the past decade. It is post-cognitive in that it analyzes the group processes that constitute collaborative learning in a computer-mediated setting. It neither defines learning in terms of outcomes nor interprets utterances in terms of mental phenomena. Without denying the reality of either individual consciousness or societal practices, it nevertheless focuses on the temporal sequentiality of small-group interaction.

The Virtual Math Teams (VMT) Project has been a collaborative effort with researchers from the Math Forum, Drexel University and Rutgers University at Newark, as well as with visiting scientists and colleagues abroad. The project is extensively documented in three books (Stahl 2006a; 2009; 2013e), nine doctoral dissertations and many other presentations (http://gerrystahl.net/vmt/pubs.html). It is a design-based research project, intended to develop technology and pedagogy for supporting online collaborative learning of mathematics. As a research prototype, the VMT environment has been used in over a thousand student-hours at the Math Forum (http://mathforum.org), as well as independently by researchers in Turkey, Singapore, Brazil and New Jersey. The current version of VMT’s software and curriculum features GeoGebra (http://geogebra.org), a popular dynamic-mathematics application.
In a typical session, three to five middle-school or high-school students collaborate synchronously online for about an hour. Often, the same group will work on a series of challenging problems during five to ten weekly sessions in an after-school or in-class setting organized by a teacher who has completed the Math Forum’s teacher-professional-development program associated with VMT. Students interact through text chat and GeoGebra actions (see Figure 2). The GeoGebra app has been converted to a multi-user version, so that actions by one student are synchronously shared with others in the group.

Figure 2. The VMT Replayer shows what everyone in the group saw and allows a researcher to step through an entire session with the controls added across the bottom. In this screenshot, the group is in the midst of constructing a solution that the researchers had never seen or thought of themselves.

The VMT environment is instrumented to provide the data necessary for analysis of group process. In order to track a group’s meaning making, one must have a complete record of all group interaction. Otherwise, one does not know if unrecorded events contributed in unknown ways to the shared understanding. This requirement involves two aspects: (a) controlling the interaction so that no group communication takes place outside of the recorded setting and (b) recording the interaction in a complete, detailed and undistorted manner. Technologies of recording data can make possible new paradigms of research. For instance, conversation analysis only came into existence with the tape-recorder for capturing and replaying speech.

Recording group collaboration in a face-to-face classroom is “messy” and often impractical: There is so much noise that clear speech capture is difficult;
transcription is laborious; and non-verbal communication through action and
gesture is impossible to capture completely. Traditional analyses generally
proceed by coding and counting. Recordings of speech utterances are
transcribed as sentences. Then sentences attributed to the individual speaker are
categorized according to some standardized schema. The number of sentences
falling into each category is compared for different individuals, groups or
experimental conditions. In the process of recording, transcription and
aggregation, many researcher interpretations are introduced (Suchman & Trigg
1991) and any sense of temporal process is lost. In particular, it is unlikely that
any surprising results (like causes of productive failure or creative group moves)
will still be identifiable. Thus, there have been practical barriers to LS making the
paradigm shift to studying group interaction. CSCL can overcome these barriers
because the computer-mediated collaborative setting makes problem-solving
processes observable and automatically fully recordable.

Since students collaborate online in the VMT environment
(http://vmt.mathforum.org), all communication and action is mediated by the
VMT technology. It is therefore possible to capture a complete record of
everything that is visible to the student group itself. The same technology is used
to replay the session for researchers, who can then slow it down or proceed
posting-by-posting and action-by-action, viewing exactly what the students in the
group all viewed (as in Figure 2). In addition, a convenient summary log is
automatically generated in spreadsheet formats (see Figure 3).
Figure 3. A spreadsheet automatically logs all text chat postings and dynamic-geometry actions of each student. It can easily be filtered by event type or re-formatted for log excerpts in publications. Columns for each student give a visual impression of the interactional flow.

The text chat is reproduced just as posted by the students, and the GeoGebra actions are listed in detail. The data of the actual interaction is available and the process of interpretation begins with the analysis, not with the data generation and reduction. Researchers can share the replayer files and spreadsheets, so that others can check any analytic descriptions for plausibility.

The VMT system’s ability to generate data, which (a) provides an automatic record of the actual interaction and (b) documents the complete group interaction, has made it useful to a number of researchers. Using this data source, they have been able to analyze group processes, rather than just individual actions or outcomes. Here are some examples from before the integration of GeoGebra, when a generic shared whiteboard was used for mathematical figures:

- Sarmiento and Stahl (2008) extended the notion by Teasley and Roschelle (1993) of a Joint Problem Space, observing how students co-construct such a shared conceptualization and how it incorporates a temporal structure, integrating past sense-making results into current discussions aimed at a projected future problem solution.
• Çakir et al. (2009) observed how a student group integrated their visual/graphical reasoning, numeric/symbolic expression and mathematical discourse in their problem-solving work within the VMT chat and whiteboard media—moving successively from one discourse to another.

• Zhou et al. (2008) looked at the important role of questioning as a common driving force in collaborative interaction, eliciting responses and providing a guiding group agency.

• Zemel, Çakir and Stahl (2009) analyzed “reading’s work” as a contribution to the analog of conversational turn taking as it is materialized in online text chat.

• Zemel and Koschmann (2013) studied how deixis and linguistic reference work within interactions in the VMT environment.

• Koschmann, Stahl and Zemel (2009) examined the nature of several key group practices in VMT collaboration.

• Wee and Looi (2009) investigated pivotal moments in group processes of mathematical knowledge building in VMT chats.

• Medina and Suthers (2013); Medina et al. (2009) probed the nature of representational practices in a series of one VMT group’s sessions, observing how practices primarily contributed by one student are later associated with the other students, as they become adopted as group practices.

• Trausan-Matu, Dascalu and Rebedea (2014) analyzed the polyphonic nature of VMT chats, graphing the intertwining of dialogical voices in a number of groups.

The idea of focusing on the group unit of analysis or group cognition does not exclude analyses at either the individual or the community units of analysis. There are important and different phenomena and processes at each of these (and other) levels. In fact, it is often most fruitful to analyze cognition on multiple levels and to see how the processes at the different levels work together. However, the simultaneous and integrated study across levels is a current challenge for CSCL. A variety of interactional resources are typically at work bridging the levels (Stahl 2013b; 2013c; Stahl & Öner 2013). Since incorporating GeoGebra into VMT, research has included designing sequences of such curricular resources to guide collaborative exploration (Stahl 2012a; 2015c).

In VMT case studies, topics in mathematical combinatorics or dynamic geometry centrally figure as interactional resources that bring together individual, small-group and community cognitive processes. Sequentiality, co-attention and
shared understanding are fundamental to collaborative learning. By observing group interaction in VMT, we can see how student groups enact these mechanisms and thereby integrate individuals into groups adopting community practices. For instance:

- In (Stahl 2011a), two students solve a high-school math problem that has stumped them for some time. The problem-solving steps that the dyad goes through as a team are strikingly analogous to how proficient math students solve problems individually. In the discourse captured in this case, one can see how the group integrates contributions from the two individual participants to accomplish a task in accordance with community standards of practice—illustrating the productive interplay of cognitive levels. A sequence of ten discourse moves (similar to extended adjacency pairs in Schegloff 2007) by the group details their sequential organization of the problem.

- In (Stahl et al. 2011), three students develop techniques for helping each other to see what they are seeing in the diagram they have drawn for a math problem. This persistent co-attention to a shared object of analysis allows the team to solve their problem as a group.

- Similarly in (Çakir & Stahl 2013), the students are able to work together because they effectively manage their shared understanding of the problem.

- Stahl (2015b) follows a group of three young girls longitudinally through eight hour-long sessions in the VMT chat room with a multi-user version of GeoGebra. It describes the display of mathematical reasoning by the team discussing the dependencies of a series of dynamic-geometry figures. By analyzing the network of mutual responses, it tracks the meaning-making process and observes how the team develops its abilities in collaboration, mathematical discourse and dynamic geometry.

When a group enters the VMT environment, it is presented with a challenging math problem, which is designed to guide the group interaction in an academically productive direction. The problem acts as a resource for the group. The group must interpret the problem statement, elaborate the way in which they want to conceive the problem and determine how to proceed.

A math problem can serve as an effective interactional resource for bridging across cognitive levels. Typically, it introduces content—definitions, elements, procedures, principles, practices, proposals, theorems, questions—from the cultural traditions of mathematics and from school curriculum. In so doing, it recalls or stimulates individual cognitive responses—memories, skills, knowledge, calculations, deductions. It is then up to the group interaction to bring these together, to organize the individual contributions as they unfold in the ongoing interaction in order to achieve the goals called for by the community,
institutional, disciplinary and historical sources. In this way, the group interaction may play a central role in the multi-level cognition, interpreting, enacting and integrating elements from the other levels, producing a unified cognitive result and thereby providing a model for future community practice or individual skill.

Group cognition is not the same as individual cognition. It relies upon individual cognition to make essential contributions; however, one cannot say that all of the cognition is reducible to the individual unit, because the work of assembling the high-level argumentative structure typically occurs at the group unit of analysis. Surely, putting together problem-solving arguments must be considered a cognitive activity as much as the memory or computation that goes into making the detailed contributions to individual steps. This group cognition may be considered to involve students in their zone of proximal development, with the expectation that they will later be able to conduct such extended problem-solving argumentation individually based on their group experiences.

In addition, the individual discourse contributions are not actually separable from the group processes. They are largely responses to what has gone before in the group interaction. These contributions are expressions that would not have occurred without the preceding opening for them and the elicitation of them by the group process. Many of the contributions are largely reactions at the group level, which reference and inter-relate resources available in the discourse context more than they introduce new elements from the personal perspective and individual background of the actor. The important knowledge-building achievement is emergent at the group level, rather than a simple collection of expressions of individual cognitive accomplishments.

Note that the emergence of group cognition is quite different from the emergence of complexity from the non-linear interaction of simple rules in chaos theory; group cognition emerges primarily through the intertwining of subtle linguistic phenomena of indexicality and sedimented shared meaning inherent in sequentially organized utterances of multiple voices.

Of course, coherent and impressive examples of group cognition—such as solving a math problem that the group members would not have been able to solve on their own—do not occur every time that people come together in conversation. In fact, the research field of CSCL has documented that desirable forms of collaborative knowledge building are disappointingly rare. The studies summarized above indicate some reasons for this. First, it is difficult to set up a group interaction where everything relevant to the cognition at the group level of analysis is captured in a form adequate for detailed analysis. It took years to iteratively design, develop and deploy the VMT group sessions to successfully generate adequate data of successful group cognition. Secondly, the group interaction must be directed and guided to focus on an appropriate cognitive task. Certain challenging math problems, carefully presented, seem to provide
effective interactional resources for stimulating interesting episodes of group cognition. Additionally, groups must work consistently to ensure the presence of certain preconditions of effective group cognition. They must persist in building longer sequences of responses to each other, they must maintain continuous co-attention to a shared focus of discussion and they must build and sustain a shared understanding of the topic of conversation.

The VMT studies listed above are focused on the small-group unit of analysis. This is consistent with other contemporary attempts to shift away from an exclusive concern with individual cognition, for instance in actor-network theory, ethnomethodology, distributed cognition and activity theory. In the VMT project, most analysis has focused on the under-researched unit of the small group (Stahl 2006a; 2009). However, recent work on VMT looks at the interactions among the individual, small-group and community units of analysis (Stahl 2013b; 2013e). This has the potential of bridging to other analytic approaches in LS and CSCL, although it raises new methodological issues about studying the relationships of the different levels.

The Foundational Relationship of CSCL to the Learning Sciences

The post-cognitive paradigm assigns an analytic priority to group cognition, as the level at which important processes of learning take place. Applying this to the study of learning is motivated by Vygotsky’s developmental principle:

Every function in the child’s cultural development appears twice: first, on the social level, and later, on the individual level; first, between people ([interpsychological], and then inside the child ([intrapsychological]). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher [human mental] functions originate as actual relations [interactions] between human individuals. (Vygotsky 1930/1978, p. 57)

Cognitive phenomena such as learning occur first in group interaction and they only subsequently—through complex and extended transformations—appear as individual skills or outcomes. In this sense, LS should be seen as founded upon CSCL. Collaborative learning is not just an optional and rare mode of instruction, but rather a foundation of learning. More generally, group cognition is a basis of human cognition: individual, small-group or community.

This paradigm argues for study at the small-group unit of analysis (Stahl 2010) in addition to the individual and community units. Too often, LS
researchers reduce group-level phenomena either to individual-psychological constructs or to societal institutions and practices. But, as we have seen in VMT case studies, there are often important practices and processes taking place at the small-group unit of analysis that are not reducible to the mental behaviors of an individual or to the institutions or established practices of a community.

This does not mean there is some kind of “group mind” at work or anything other than the interaction of the students. Rather, it means that the analysis of cognitive achievements may be most appropriately conducted at the group unit of analysis—in the VMT context, in terms of the interplay of the text-posting and geometric-drawing actions shared by the group.

CSCL is not the science of some existing, objectively observable phenomenon, like physics or psychometrics. It is the search for a new form of learning—taking advantage of technologies that are yet to be developed and group processes that are difficult to observe and have largely gone unnoticed. Therefore, it cannot be studied in the manner of a summative assessment, by comparing measureable learning outcomes. It is more of a design science, using design-based research to transform “existing situations into preferred ones” (Simon 1981).

To guide redesign, it is not sufficient to “predict” the percentage increase in outcomes that is attributable to a particular, currently available technological condition. What is needed is insight into how students in realistic situations may actually make sense of and take advantage of possible technologies, as well as what barriers students may encounter in trying to use them. This means looking at how groups of students interact with various technological artifacts and observing their meaning-making processes, their enacting of the technologies and their problem solving as mediated by the technologies.

Of course, not all groups of students will act the same way under similar conditions. Groups are unique—with students at different zones of proximal development for different skills and with interactions highly situated within unreproducible discourse trajectories. Therefore, statistical generalization is not a relevant goal in such research. What one seeks, rather, is a detailed understanding of the practices that are actually found to be at work in observed cases.

According to ethnomethodology, communities tend to use shared practices (Garfinkel & Sacks 1970). Otherwise, intersubjective sense making would not be possible—any more than communication would without a common language. Therefore, the practices that one observes in a single case may be representative of widely used practices. Researchers familiar with a domain—such as experienced math educators—can often tell what seems like a typical group behavior within that educational arena.
LS and CSCL have made significant progress in recent decades, as documented in (Sawyer 2006) and in the current volume. However, it may be timely to pursue a new research paradigm explicitly—one in which CSCL plays a foundational role. For the CSCL and LS research communities to make the major paradigm shift advocated here will involve significant re-tooling and adoption of new methods. It will also require increased collaboration with colleagues in social science who are more familiar with analyzing interaction and language and with formulating rigorous descriptive accounts of group-interactional processes. Fortunately, the requisite technological recording capabilities are available and the evocative research questions are at hand.

The settings studied by LS and CSCL today are complex. Many diverse studies can contribute to an understanding of the learning taking place. Such studies can pose a broad spectrum of research questions, each with its own theoretical framing and methodological approach. Certainly, traditional quantitative and qualitative analyses at the individual unit of analysis can provide important parts of the picture, as can considerations of social practices and community participation. However, it is also necessary to consider the temporal processes of group interaction, through which the individual and the community are often mediated and through which learning takes place as a process, not just as an outcome.

In his reconsideration of the CSCL paradigm, Koschmann (2001p. 21) concluded that “we have yet to develop a consensus within the CSCL community with regard to what it means to learn and how to study the process.” I have argued here that a paradigm-shaping research question for LS would treat learning as essentially an intersubjective, interactional process, and would study it by investigating the dynamic developmental processes through which individual, small-group and community cognitive practices emerge.

The seminal analysis by Teasley and Roschelle (1993) pursued a specific version of this question by asking how dyads of students created a joint problem space around a computer representation of velocity and acceleration. The VMT Project is currently pursuing a different approach to the same question by exploring how students co-construct interactional, group-cognitive and mathematical practices in small online groups mediated by collaborative-dynamic-geometry tasks and tools (Stahl 2013e; 2015b). Following approaches like these, research in a post-cognitive CSCL paradigm can lead research in LS by working out the interactional foundations of all learning through taking advantage of technologies, pedagogies and understandings afforded by CSCL.
From Intersubjectivity to Group Cognition

The question of how it is possible for people to understand each other has been a controversial theme throughout the recent history of philosophy. It is a foundational issue for the social sciences, in which researchers try to understand the behaviors and statements of other people. It is of particular relevance to CSCW and CSCL, where participants have to understand, work with and learn with each other.

Philosophers have posed the issue of how an individual can understand another and how a small group or community can have a joint understanding, shared intentionality or we-awareness. Studies of CSCW not only adopt insights from the philosophy of intersubjectivity to ground their methodology, they also contribute to the analysis of how intersubjectivity is established in concrete settings, including in virtual environments. Similarly, CSCL research can investigate how groups of people learn to construct intersubjective understandings in both traditional and technologically enhanced interactions.

While classical phenomenology of intersubjectivity started from the cognitions of a solitary mind, the notion of intersubjectivity has subsequently shifted to a more social view. Recent studies of intersubjectivity suggest a structure of group cognition, which can provide a foundation for collaboration in work and learning that incorporates but transcends individual cognition.

While ‘intersubjectivity’ is a modern term, it points to an issue that is both as old as philosophy and as current as the lead article (Tenenberg, Roth & Socha 2015) in the CSCW journal special issue on we-awareness. Intersubjectivity is what makes we-awareness possible. By referencing a realm between or encompassing multiple people, intersubjectivity raises the question of whether knowing, thinking or being aware are at base matters of individual humans or collectivities.
The following historical review of the philosophy of intersubjectivity will trace a shift from a foundation in individual minds to one in groups or communities. It will consider the central statements concerning intersubjectivity from Husserl, Schutz, Heidegger, Merleau-Ponty, Hegel, Marx, Vygotsky and Tomasello. Implications of the philosophic conception of intersubjectivity for CSCW (computer-supported cooperative work) and CSCL (computer-supported collaborative learning) methodology—in which the analytic foundation in individual or group cognition is currently highly contentious—will then be suggested and related to research in these fields.

The issue of intersubjectivity is paramount to our times. The major geopolitical issues of the day concern how people around the shrinking globe can understand each other and relate in unity to their shared world. How can the rich and the poor see eye to eye on global ecology; how can former colonial powers and former colonies work together for peace and mutual benefit; how can populations with incompatible politics, ideology, religion and economic interests co-exist? We do not adequately grasp how people understand each other even in dyads, let alone in international communities. Researchers in CSCW and CSCL could contribute to such a comprehension, but they tend to get distracted with methodological concerns based on outmoded philosophies and approaches misappropriated from the natural sciences.

The problematic of intersubjectivity emerged in response to the growth of the social sciences a century ago. The first explicit systematic discussion was in the phenomenology of Husserl, grappling with issues in traditional philosophy. Although the historical movement from intersubjectivity to group cognition followed multiple intertwined paths, this essay will present a single conceptual thread, aligned with facets of the Tenenberg, et al. lead article. It will review the core discussions of intersubjectivity in the primary philosophic texts that defined the concept.

As we will see, the term ‘intersubjectivity’ is ambiguous. It can refer to the problem of how two or more minds can inter-relate: understand each other and work together from their individual cognitive positions. It can also refer to a form of joint cognition that is shared by a group and transcends, unifies or even founds the cognition of the participating individuals. This essay will trace an evolution in philosophy from the former view to the later, and will propose a view of intersubjectivity as group cognition, appropriate to CSCW and CSCL.
The Philosophy of Subjectivity: Plato, Descartes, Kant

Socrates was the poster child for the self-reflective individual, who radically examined his own life and thought. However, in the end he submitted to Athenian society as the collectivity to which he fundamentally belonged. Perhaps horrified by the consequence of Socrates’ refusal to break with his corrupt, irrational and unheeding community, Plato (340 BCE/1941) metaphorically left his fellow citizens behind in the dark cave of their traditions and illusions to emerge into true knowledge as an isolated individual. Thenceforth, truth, knowledge and learning were no longer matters founded in traditional society, but concerned eternal ideas discoverable through individual critical reflection.

The focus on individual thought found its ultimate formulation in Descartes (1633/1999). In his argument—popularly formulated as “I think, therefore I am”—Descartes claimed that as much as he tried to doubt the reality of everything, he could not doubt that he was thinking, because his doubt was itself an instance of him thinking. If he was thinking, then there must be a subject (namely him) who was doing the thinking. Descartes thereby established as a foundation for philosophy and all knowing that an individual thinking subject existed. This raised subsequent problems, which were much harder for Descartes and his successors to address: how can this radically doubting individual subject be certain about knowledge of any object in the physical world (the problem of epistemology) and how can this isolated individual subject be certain about knowledge of other people’s minds (the problem of intersubjectivity). How can one even know that a world or that other people exist external to the individual thinking subject (the problem of solipsism)?

There were many attempts to address the problems left in Descartes’ wake. These produced philosophies of empiricism, rationalism, materialism, idealism, etc. Some of these were adopted as foundations of scientific method and are still assumed in many contemporary research methodologies. Kant (1787/1999) came up with a synthesis of the major philosophic approaches of his time, still focusing on the individual human mind as the seat of pure reason. He argued that the only access we have to the world is to versions of objects that we have constructed ourselves from our sense perceptions. We structure what we sense from the world that is external to our individual minds. We do so in terms of categories of time, space and causality, which we impose in constructing the world as knowable. That provides us with a view of the world that makes sense to us, with persistent, meaningful objects. Kant’s solution to the problem of epistemology provides a form of constructivism that makes impossible ‘objective’ knowledge (other than logical deductions) in a naïve sense. Kant demonstrated that there are many questions that are meaningless to pose—often
because they presume to peek behind the constructions that our understanding
of the world unavoidably erects.

The Phenomenology of Intersubjectivity: Husserl

While philosophy has always been concerned with the nature of subjectivity, the
first major discussion of inter-subjectivity was by Husserl. He devoted his
popular introduction to phenomenology to the problem of intersubjectivity. His
*Cartesian Meditations* (Husserl 1929/1960) was presented at the Sorbonne in 1929.
(Merleau-Ponty was in the audience as a student.) This was a couple years after
Husserl’s student and assistant, Heidegger, had published *Being and Time*, but
Husserl’s presentation was as yet unaffected by that.

Husserl was concerned with the crisis of the philosophical foundations of
the sciences. Dilthey and others had differentiated the human sciences from the
natural sciences. Einstein and quantum theory were shaking the physical sciences
with the idea that observation was relative to the observer. The foundations of
logic and mathematics were in dispute. Weber and others were formulating
social sciences (linguistics, anthropology, as well as sociology) in terms of
meaning and interpretation, difficult to objectify.

Husserl began from Descartes’ argument. It starts with the solitary subject
(‘I’) doubting everything except its own existence. In five chapters or
‘meditations,’ Husserl builds toward the central problem, intersubjectivity: How
can I know another person—that he exists or what he means when he speaks?
For a social science today, such as CSCW, this asks: How does one person relate
to co-workers as equally human, how does one understand the meaningful
actions and statements of others? Also: How does a researcher analyze the
meaning created in the discourse and in the work products of cooperating
workers?

After introducing Descartes’ position in his first meditation, Husserl shows
how minds construct meaningful objects. At first, cognition is intentional, that
is, directed toward some phenomenon. For instance, if my cognition is directed
toward a six-sided die, I perceive at any instant only evidence of certain sides.
However, over time my consciousness can synthesize the die as having six sides,

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1 The masculine pronoun is used throughout this essay to refer to people of all genders,
in keeping with traditional English grammar and philosophic usage.

2 The notion of intentionality was first developed by Husserl’s teacher, Brentano (1874).
As the lead article explains, it means that consciousness is always consciousness of
something, always directed at something.
perceptible from different perspectives. Then the die is intended by my consciousness as given with more than the immediate evidence. The meaningful die is temporally constituted by a series of perceptions and synthesizing acts in my stream of consciousness. I understand the perceived view of the die as having a horizon of possibilities, anticipations or potential remembrances that is given with the immediate perception as belonging to the meaning of the phenomenon of the observed view of the die. Husserl’s third and fourth meditations outline his extensive phenomenological analyses of how the solitary subject constitutes its world and its lived temporality, starting from elementary cognitive experiences.

For Husserl, we construct or constitute our experiences of things, including other people, through sequences of cognitive acts, which are generally not conscious, but pre-reflective. Our knowledge of another person is constituted through our own processes of constructing our experience of them. We can, for instance, construct an understanding of someone else’s behavior as the behavior of a person who is human like us, has a stream of consciousness like ours and has understandings like ours. We can assemble evidence for our understanding of the other person from experiences we have had—both our experiences of the other person and our own experiences that are similar or relevant. For instance, we observe our own bodies and those of others—and we see that the other is like us.

In his concluding fifth meditation, Husserl reaches the goal of his presentation and gives us a summary of the first major extended analysis of intersubjectivity. He departs from Descartes and argues that we can experience other people as also sentient beings who experience the world as we do. In fact, this makes the world a shared, intersubjective one. We experience the socially shared world from our own perspective and we see other people as also experiencing this same world from their positions:

I experience others in shifting experiential manifolds. On the one hand, as objects in the world. Not just as mere natural things, but also experienced as psychically active in the natural bodies to which they each belong. On the other hand, I experience them simultaneously as subjects of this world, as experiencing this world—this same world that I experience myself. They are experiencing it with me, as I experience it and as within it I experience them. Even within my purely cognitive life, I experience the world including other people and the associated meaning not as a so-to-say private construction of synthesis, but as other than mine, as intersubjective, as existing for everyone, as having its objects accessible to everyone…. To the character of the world and particularly of nature as objective, there belongs its being there for everyone, as constituted by us.
whenever we speak of objective reality. To this belongs the objects of
the experienced world having mental characteristics, which refer to
human subjects by their origins and meaning—and in general refer to
other subjects and their actively constituting intentionality. This
includes all cultural objects (books, tools and all kinds of works, etc.),
which also carry with them the experiential meaning of being there for
everyone. That is, for everyone of the corresponding cultural
community, such as the European or more specifically the French.
(Husserl 1929/1960, §43, my translation)

Husserl overcomes the solipsism of Descartes by showing that I experience
others as fellow subjects in a shared world. However, this all takes place in my
own consciousness and experiences. So it is not meaningful to ask if my
understanding of the other person’s behavior is identical to the other person’s
understanding of their own behavior. The gulf of intersubjectivity is spanned by
Husserl in that we can construct an understanding of the other person as a
person, with their own understandings. Nevertheless, we cannot erase the gulf
and obtain direct knowledge of their understanding. Any two people construct
their own understanding of the shared world (including themselves and each other)
from the perspective of their own subjectivity (stream of consciousness,
personality, personal history, body position).

The Social Science of Intersubjectivity: Schutz

Schutz explicitly applied Husserl’s approach to the social sciences, specifically to
Weber’s sociology. In 1932, he published a detailed and relatively clear book on
the meaning-full construction of the social world (Schutz 1932), centered around
a chapter on “Foundations of a theory of intersubjective understanding.” While
occasionally referencing Heidegger, Schutz remained true to Husserl’s
phenomenology, starting from the cognitions of an individual consciousness and
constructing the intersubjective world from that basis. This was also consistent
with the methodological individualism of Simmel and Weber, which held that
“all concrete social phenomena should be traced back to the modes of individual
behavior” (Schutz 1932/1967, p. 4).

Schutz starts from Husserl’s conclusion of the intersubjectivity of the
world, namely that people take for granted the existence of other people as
having the same kinds of temporal streams of consciousness and as sharing the
same social world. However, since people constitute the world from their own
perspective (in terms of their own bodily location, personal history, ingrained
habits, action goals and subjective experiences), “the concept of the other
person’s intended meaning remains at best a limiting concept” (p. 98). We can only approach an understanding of another’s cognition to a degree and without certainty.

To understand another person takes a reflective act. The other person typically does not understand his own action in this way: he is simply acting, not reflecting on his action. Thus, it does not even make sense to ask if a researcher’s understanding of a subject’s action corresponds to the subject’s own understanding, since the subject probably does not have that kind of reflective understanding. If a researcher tries to triangulate his interpretation by asking a subject questions (in a test, a questionnaire, an interview, a focus group), then the subject may start to reflect on the relevant prior actions, but his newly constructed understanding or response was not something present at the time of the action, let alone motivating it. Nor is the subject’s retroactive self-understanding qualitatively superior to an observer’s understanding of the subject, except that the subject may have access to a richer array of information about himself and his past. Like the researcher’s analysis, the subject’s self-understanding is also a speculative reconstruction from a series of perceived experiences.

Schutz provides analyses of meaning making, sign systems and artifacts, as they enter into our understanding of other people and of their communications, actions and interactions. He also describes concepts of ‘in-order-to motives’ and ‘because motives,’ which can be used for understanding statements and actions, without attributing explicit knowledge to the actor. These feed into Schutz’ interesting discussions of the thou-orientation, the we-relationship, face-to-face situations and direct social observation.

The **thou-orientation** is a pre-reflective awareness of another person as a fellow human, who has consciousness and experiences similar in kind to my own. It thus embodies the intersubjectivity in which others are recognized as indubitable, aware, thoughtful and human. To understand another in this way is to attribute meanings, desires and plans to him. It is the first stage of intersubjectivity as a relationship between two individual subjects.

When the thou-orientation becomes reciprocal, it forms a **we-relationship**, in which another and I experience the world together as a shared world. Schutz provides this example: “Perhaps while I was following the bird’s flight I noticed out of the corner of my eye that your head was moving in the same direction as mine. I could then say that the two of us, that we, had watched the bird’s flight” (p. 165). Although we have experienced something together, that does not mean that we had the same subjective experience. For me to think about your experience, I have to step back from our we-relationship and reflect on evidences about your experience that are available to me. This is a second stage of intersubjectivity including reciprocity: I am aware that you are experiencing
the same world as I am and we are doing it together. Schutz’ we-relationship is
the foundation for the lead article’s we-awareness.

When two people are engaged face-to-face, they participate together in an
ongoing series of acts of meaning-establishment and meaning-interpretation
(such as elicitation/response pairs of discourse utterances, in which I say
something and you respond, thereby establishing the meaning of my utterance
through its implicit interpretation by your response). In orienting to objects of
joint attention, the participants experience the objects as common to both their
experiences. They are simultaneously aware of what each other experience as
being experienced together. The shared intersubjective world is constituted by
this experience in the face-to-face situation. Over time, I understand my partner
in terms of his motives (personality, habits). Furthermore, I can check my
understanding of the other by asking him questions (e.g., to jointly create
meaning and to avoid or repair potential misunderstandings). This all takes place
within the merged experiential streams of the face-to-face situation. Although
Schutz does not discuss the face-to-face mode of intersubjectivity in any detail,
he hints here at an intersubjectivity that is more than the sum of its parts, the
two individual subjectivities. Meanings are created through the interaction
between the participants; there are group processes like repair of understandings;
and the experience of the world is partially shared, not completely subjective.
Schutz’ face-to-face intersubjectivity provides a brief foretaste of group
cognition.

Schutz then contrasts the face-to-face situation (e.g., of participants
collaborating) with direct social observation (e.g., by a social-science researcher).
Direct social observation is very different from the face-to-face situation. The
observer is not engaged in the same undertaking as his subject, nor is he engaged
with the subject in a shared context of action. Furthermore, the observer does
not have the same kinds of access through interaction to check on and repair his
understandings of the subject’s subjective experiences, motivations or attempts.
The close mutuality and reciprocal mirroring of the face-to-face situation is
missing in a context of objective observation. Schutz specifies three possible
indirect approaches for scientific observation of a subject’s motives: An observer
can interpret the subject’s behavior in terms of what he imagines he himself
might have done under the circumstances. Alternatively, he can take into
account the customary behavior of that kind of person (e.g., applying Weber’s
ideal types). Finally, he can interpret the observed behavior “in terms of the
effect which it actually has and assume that the effect is what was intended” (p.
175). These modes of understanding other people and of intersubjectivity appear
in various methodologies of CSCW and CSCL research.
The Being of Intersubjectivity: Heidegger

By the time Husserl’s and Schutz’ analyses of intersubjectivity were published, Heidegger’s implicit repudiation of these theories was already widely read. Although Heidegger emerged from the Husserlian school of phenomenology and was deeply steeped in traditional philosophy, his Being and Time presented a radical rejection of the starting point of individual consciousness. In this sense, he left behind not only the constructivism of Kantian pure reason, but also the cognitivism of any methodological individualism. Heidegger’s analysis of human existence began with the unity of being-in-the-world, where people exist through their essential involvement in the world. This involvement includes being-there-together in the shared world with other people.

Heidegger’s analysis of being-there-with-others (Heidegger 1927/1996, §§25-27) is laced with barbs against the positions of Husserl and Schutz. Heidegger refers to the enterprise of seeking a transition from the isolated individual to the other as a “mis-understanding” and explicitly rejects the conception of the unity of the self “as the identity of the I maintaining itself in the multiplicity of its ‘experiences’” (p. 122).

Human being as our openness to the world is defined according to Heidegger, first and foremost, by the collectivity of other people, with whom we are concerned and with whom we share a joint world, filled with meaningful artifacts and natural objects that we deal with together. However, this collectivity is described abstractly by Heidegger—not in terms of our family, friends, colleagues, neighbors, community or society. In fact, it is portrayed in rather dark tones, as an oppressive or at least obscuring view of the world through the outlook of an unenlightened mass culture.

Heidegger argues that because we are caught up in this distracting and obscuring culture and are constantly busy with other people, with the objects in the world of our concern and our projects involving them, we cannot see our own true nature as being-there-with-others. Rather, we see things—including other people and even ourselves—in terms of an ontology of physical objects and mental ideas (à la Plato, Descartes and the common sense of the collective). Unfortunately, after his brief but central and pivotal analysis of being-there-with-others, Heidegger shifts from the social basis of human existence, which he had finally uncovered, to a focus on the individual self as a secondary ontological mode, which supposedly provides greater understanding of human being than the collective view. He values this derived mode as more “authentic,” although ironically it is close to the individualistic reflective mode of Husserl. Heidegger, thus, retreats from the social foundation he briefly established. By not elaborating this more concretely through contact with the other mainstream of German philosophy developed by Hegel and Marx, Heidegger remains at the
level of politically conservative cultural criticism (Adorno 1964/1973) and heads toward his fateful political error (Stahl 1975).

The Corporeality of Intersubjectivity: Merleau-Ponty

Merleau-Ponty studied both Husserl and Heidegger carefully, including their responses to Descartes’ problem of intersubjectivity. Merleau-Ponty (1945/2002) fleshed out their analyses with an in-depth analysis of the role of the body and of embodied perception in human being and thinking. His chapter on other people and the human world comes as the culmination of his phenomenological description of human existence. He argues that the experience of another person—such as my sense of the other’s grief or anger—is given immediately in my perception of his bodily contact and expression, not mediated through some form of my reflection on what his inner experiences must be like based on remembrances of similar experiences of my own (p. 356). We thus strive to project a shared world, in which we can communicate, for instance about our grief or anger. We each do so from our own bodies, as corporeal actors.

Intersubjectivity is given with our being embodied in a shared world and forms a basis for our subjectivity. Intersubjectivity could not be “constituted” subsequently by isolated individual consciousnesses. As Merleau-Ponty says, “My greatest attempt at impartiality would never enable me to prevail over my subjectivity (as Descartes so well expresses it by the hypothesis of the malignant demon), if I had not, underlying my judgments, the primordial certainty of being in contact with being itself; if, before any voluntary adoption of a position, I were not already situated in an intersubjective world” (p. 355).

Merleau-Ponty adopts Heidegger’s view of being-there-with-others as fundamental to the human condition. However, he does so more concretely and persistently. He refers to the perception of the other’s body as material, meaningful and expressive. He cites evidence from child development that infants exist in a shared world without even differentiating themselves from others—so that subjectivity is seen to be a derived and learned phenomenon, not a Cartesian starting point.

In addition, Merleau-Ponty looks at the role of language in the perception of other people. Language is essentially social; it transcends the individual and it merges the perspectives of multiple speakers. He describes eloquently how dialogue can establish a shared thinking in the verbal interaction of two people:
My thought and his are interwoven into a single fabric, my words and those of my interlocutor are called forth by the state of the discussion, and they are inserted into a shared operation of which neither of us is the creator. We have here a dual being, where the other is for me no longer a mere bit of behavior in my transcendental field, nor I in his; we are collaborators for each other in consummate reciprocity. Our perspectives merge into each other, and we co-exist through a common world. In the present dialogue, I am freed from myself, for the other person's thoughts are certainly his; they are not of my making, though I do grasp them the moment they come into being, or even anticipate them. And indeed, the objection which my interlocutor raises to what I say draws from me thoughts which I had no idea I possessed, so that at the same time that I lend him thoughts, he reciprocates by making me think too. It is only retrospectively, when I have withdrawn from the dialogue and am recalling it that I am able to reintegrate it into my life and make of it an episode in my private history. (p. 354)

Through elicitation and response, the utterances of people in dialog produce a cognitive stream that is not attributable to either speaker individually, but is a group process that only makes sense as such. This is a description of collaboration as an intersubjective form of cognition. There is a common world, in which the two personal perspectives are integrated in a single process of meaning making—a “shared fabric.” The view of an individual's contribution to the dialog is a retroactive view, the result of subsequent reflection and appropriation.

Merleau-Ponty’s description of the intersubjective source of my own creativity is particularly striking. The other draws from me thoughts “which I had no idea I possessed.” Of course, I did not “possess” such thoughts ahead of time—they emerged from the discourse. Nevertheless, they were understood by everyone as being my thoughts, from my perspective and due to my agency. Here we get a glimpse of the power of intersubjective collaboration.

This model of intersubjectivity goes beyond Husserl’s and Schutz’ analyses of the individual’s “transcendental field.” It also escapes Heidegger’s version of intersubjectivity as an obfuscating mass culture. Merleau-Ponty agrees that one can step back from intersubjective engagement to reflect on one's personal life, but now with positive insights about one's own thinking that would not otherwise have occurred. Finally, we have a conception of intersubjectivity that values the potential of collaboration and of our concrete joint life in a shared world. Here, intersubjectivity can be a primordial experience, which provides a foundation for individual consciousness.
In recent decades, followers of phenomenology have adopted the shift of starting point from the individual to the shared world, pioneered in Heidegger’s being-there-with-others, the later Husserl’s life-world and Merleau-Ponty’s intersubjectivity. For instance, Schegloff (1991p. 168) writes, “In Western tradition, it is the single, embodied, minded individual who constitutes the autonomous reality.” He then contrasts the view of phenomenologically inspired ethnomethodology and conversation analysis to this earlier dominant cognitivist tradition: “Interaction and talk-in-interaction are structured environments for action and cognition, and they shape both the constitution of the actions and utterances needing to be “cognized” and the contingencies for solving them.” As their names suggest, ethnomethodology describes the pervasive methods that people use for creating social order during their interactions, and conversation analysis describes the patterns of talk that people use to support intersubjective understanding of the public meaning that is thereby created in the shared world. This approach details the rich and orderly variety of mechanisms that are used in human interaction to constitute and maintain intersubjectivity.

In addition to his phenomenological roots, Merleau-Ponty appreciated the other major philosophic tradition in twentieth-century European thought, that of Hegel and Marx, to which we turn next.

The Dialectic of Intersubjectivity: Hegel and Marx

When the movement of social history became conspicuous with the American and French revolutions, the march of Napoleon and the early stirrings of the industrial working class, Hegel captured the nature of his dynamic times in his philosophy. His early lectures in particular defined a break with Kantian methodological individualism and described the social nature of man (Habermas 1967/1971; Hegel 1807/1967). This led to a philosophic approach to subjectivity contrasting to that of Husserlian phenomenology, which had remained neo-Kantian.

Until Hegel, human nature and human cognition were conceived as based in the individual person, as fully determined from birth ahistorically or universally—not dependent on one’s biography or social context. The theories that minds develop (Freud), that social relations transform (Marx) or that humanity evolves (Darwin) all came after Hegel—in process-oriented sciences inspired by his philosophy. For Freud, Marx and Darwin, to understand a psyche, a social formation or a species requires understanding the history of its development, complete with its conflicts and resolutions.
Hegel outlined a dynamic view, in which mind develops all the way from primitive sense perception to sophisticated self-consciousness and cultural worldview. In the methodological Preface to his most influential presentation of the development of mind, Hegel (1807/1967) wrote that one must analyze a phenomenon by looking at its unity as the result of its clashing temporal appearances:

The bud, the blossom and the fruit’s fluid nature make them into moments of an organic unity within which … one is equally as necessary as the other…. The subject matter is not exhausted in its ends; rather, it is exhaustively treated while it is worked out. Nor is the result that is reached the actual whole itself; rather, the whole is the result together with the way the result comes to be…. What is the most difficult of all is to grasp both what unites the process and the result, and to give a full exposition of what that is. (§2 & 3, my translation and italics)

Let us see how Hegel treated interaction between two people in his famous master/slave dialectic. A person first becomes aware of himself as a particular individual at this developmental stage within Hegel’s system. The analysis focuses on the interaction of people and involves them working with objects in the world. The cognitive effect (self-consciousness) is a result of the whole dynamic of the interaction, not a pre-existing causal agent within the interaction. The prototypical interaction is here that of a worker creating an artifact; the worker recognizes himself as reflected in the product that he created to meet the needs of another person:

Work gives form to its object. The worker’s transforming relationship toward the object is transformed into the object's form and becomes something persisting, because for the worker the object gains self-sufficiency. This transforming mediation—the activity of forming—is also the individuality of consciousness or the pure being-for-itself of consciousness, which in the work process now steps out of consciousness and takes on the character of persistence. The consciousness of the worker thereby arrives at a perception of the self-sufficient artifact as a perception of his self. (Hegel 1807/1967, p. 238, my translation)

Hegel shows how human consciousness emerges through productive activity in the intersubjective and physical world. The worker and the master (for whom the object is produced) are formed as such (i.e., as self-conscious individuals) through the interaction with each other and with artifacts (tools and products of work) in the world. Hegel describes the emergence of self-consciousness from within the process of mutual recognition of self, world and other. In particular, it is the worker, who produces an artifact in the physical world at the bidding of an other, who is then able to perceive his labor as
externalized and made persistent in the artifact. The worker’s self-consciousness emerges through his activity in the shared world, where he comes to see himself as objectified in his artifacts and through the eyes of others.

Marx (1867/1976) builds on this analysis of social interaction. He situates Hegel’s idealist analysis in the historical context of early capitalism. The artifact that is produced by the worker’s labor and that externalizes his self within its social relations to other people is specified within settings of capitalist production into a commodity (an artifact produced for sale on the open market). The worker’s self-consciousness is reified, alienated and fetishized because the commodity that reflects his identity is no longer his (but the capitalist’s, who sells it) and because his social relations to potential users of the artifact are transformed into the abstract monetary value of the commodity. The meaning of the labor that went into forming the product’s use-value undergoes multiple complex transformations: it is externalized into an artifact, the artifact enters commodity relations and the commodity is reflected back to the worker as monetary exchange-value belonging to his boss. For Marx, individuals in capitalist society are analyzed as results of their interactions as wage laborers, owners of the means of production or consumers of commodities. He critiques the traditional notion of the abstract individual consciousness as an ideology of individualism that obscures concrete, historically specific human reality.

In his methodological Grundrisse, Marx (1858/1939) identifies the interaction in which the worker exchanges his labor time for the capitalist’s wages as the “cell form” for analysis. His analysis in Capital (1867/1976) starts out from the simple dyadic interaction of a worker exchanging the product of his labor with another person. As his inquiry into social production in the capitalist era develops, this elemental intersubjective relation of production is mediated by its dialectical relationship to technology as the social means of production (e.g., the factory system and machinery in their historical development).

Intersubjectivity in this approach of Hegel and Marx is a concrete social and historical product of human labor with material artifacts. The subjectivity of individuals is a subsequent by-product of their interactions within the shared social world. The Kantian view of the individual mind producing the world is stood on its head. Mind is seen as a social product and individualism is characterized as an ideology serving competitive capitalism.

In a contemporary extension of this tradition, Habermas (1971/2001) has argued for viewing communicative action as the basis for intersubjectivity and social theory. He starts by explicitly rejecting the individualism of Kant and Husserl, which do not allow escaping from monadic subjectivity. Incorporating the linguistic turn of Wittgenstein (1953), Habermas reconstructs the possibility of moral behavior and social science from the interpersonal relationship between
people engaged in communicative action. The dialectical tradition takes as its starting point the social interaction among people in place of Descartes’ isolated subject. It focuses on the dynamic and conflictual mediations of this interaction within the concrete, historical world.

The Mediation of Intersubjectivity: Vygotsky

Vygotsky provides a psychology of human cognition appropriate to Marx’ methodology of social science. He adopts Marx’ analytic cell form: the interaction among people mediated by artifacts. Artifacts are both physically present in the world and meaningful to people. For Vygotsky, the notion of artifact encompasses both tools and language. Their meaning is not projected from individual minds, but is intersubjectively emergent from social interactions, as in the dialectical presentations of Hegel and Marx.

Consider Vygotsky’s programmatic effort to show how the individual human mind is grounded in activity within the physical and social world. His description of the genesis of the pointing gesture illustrates a typical early experience of meaning for a small child; it shows how the meaning of this ubiquitous symbolic artifact is created in the intersubjective world and only subsequently incorporated (internalized) in the child’s own sense-making repertoire:

We call the internal reconstruction of an external operation internalization. A good example of this process may be found in the development of pointing. Initially, this gesture is nothing more than an unsuccessful attempt to grasp something, a movement aimed at a certain object, which designates forthcoming activity…. When the mother comes to the child’s aid and realizes this movement indicates something, the situation changes fundamentally. Pointing becomes a gesture for others. The child’s unsuccessful attempt engenders a reaction not from the object he seeks but from another person. Consequently, the primary meaning of that unsuccessful grasping movement is established by others…. The grasping movement changes to the act of pointing. As a result of this change, the movement itself is then physically simplified, and what results is the form of pointing that we may call a true gesture. (Vygotsky 1930/1978, p. 56, italics added)

Here we see the intersubjective genesis of the meaning of a pointing gesture. The recognized, practical and formalized gesture becomes an artifact: it embodies meaning in the physical world. The meaning of the pointing gesture is its reference to that which is pointed at. The baby and the mother intended
some object together in their shared world. Their intersubjective gesture entails that the baby and the mother recognize each other as people who can have intentions and who can recognize intentions of other people. This is a first glimmer of intersubjectivity, in which the baby becomes aware of his own and other people’s intentionality. (Of course, the baby cannot yet express this awareness in any verbal or conceptual sense, but only behaviorally.)

The key point is Vygotsky’s analysis of this gesture artifact as a product of two people interacting, recognizing each other as subjects and together intending something in their shared world. This pointing gesture is a ubiquitous form of reference or deixis, used throughout the human world to support joint attention. In the origin of the infant’s first gesture, we already see a model of intersubjective, shared understanding of meaning. The subsequent usage of this pointing gesture is premised upon the mutual recognition of an underlying intention, which emerged within the intersubjective mother-child interaction.

This view of intention as co-constructed in the world stands in sharp contrast to the rationalist assumption that individuals “have” aims—stored mental contents produced by logical calculations of self-interest as though by a homunculus in their heads—which they then express in speech or action. Marx, Wittgenstein and Heidegger (the primary founders of twentieth-century theory)—and their followers—soundly reject this cognitive picture of agency (see, e.g., Dennett 1991; Dourish 2001; Dreyfus 1992; Ehn 1988; Suchman 2007).

The traditional conception of individual agency—in which human actions are caused by mental representations, cognitive schemas or prior plans—contributes to the difficulty of overcoming cognitivist habits of thought. Drawing on contemporary philosophy and social science, Emirbayer and Mische (1998p. 962) conceptualize agency in Heideggerian temporal terms (with hints of Bourdieu, Giddens and Habermas). They define agency as: “a temporally embedded process of social engagement, informed by the past (in its “iterational” or habitual aspect) but also oriented toward the future (as a “projective” capacity to imagine alternative possibilities) and toward the present (as a “practical-evaluative” capacity to contextualize past habits and future projects within the contingencies of the moment).” Such a post-cognitive concept of agency could be applied at the group unit of analysis, forming a concept of “group agency,” potentially driving collaboration. This could inform CSCW and CSCL theories. In developing a post-cognitive view of intentionality, it is important to reconsider the notions of agency and causality—as Latour (1990; 1992; 2013) does by extending them to collectivities and to artifacts in actor networks.

A paradigm shift from the traditional focus on individual consciousness to a foundation in intersubjectivity can be motivated by noting anomalies in the
established views (Kuhn 1972). Consider an anomaly in the educational-psychology paradigm of measuring learning outcomes as uncovered by Vygotsky’s analysis of learners’ zones of proximal development. In a formulation evoking Hegel, he writes of the need to analyze developmental processes, not just outcomes: “The zone of proximal development defines those functions that have not yet matured but are in the process of maturation, functions that will mature tomorrow but are currently in an embryonic state. These functions could be termed the ‘buds’ or ‘flowers’ of development rather than the ‘fruits’ of development.”

He then cites a study in which children “could do only under guidance, in collaboration and in groups at the age of three-to-five years what they could do independently when they reached the age of five-to-seven years” (Vygotsky 1930/1978, pp. 86, 87). CSCL can be seen precisely as such an effort to stimulate students within their zones of proximal development under guidance, in collaboration and in groups. If the desired results do not show up as learning outcomes measurable in individuals (outside of their group context) for several years, then the key effect will be systematically missed by traditional methods of testing individuals. The failure of the cognitive paradigm of instructional research to account for processes in the zone of proximal development—so central to learning—should be considered an anomaly, suggesting the need for a paradigm shift.

In his less quoted section on “Problems of Method,” Vygotsky (1930/1978 pp. 58-75) called for a new paradigm of educational research almost a century ago. Arguing that one cannot simply look at visible post-test results of an experiment, he approvingly quoted Marx: “if the essence of objects coincided with the form of their outer manifestations, then every science would be superfluous.” He then emphasized, “To study something historically means to study it in the process of change; that is the dialectical method’s basic demand. To encompass in research the process of a given thing’s development in all its phases and changes—from birth to death—fundamentally means to discover its nature, its essence.”

In Vygotsky’s proposed method of “double stimulation,” a child is confronted by both an object to work on and an artifact to support that work; she learns to mediate her understanding with the use of the artifact. However, Vygotsky does not call for a controlled experiment that compares learning outcomes with and without a furnished artifact. “The experiment is equally valid,” he points out, “if, instead of giving the children artificial means, the experimenter waits until they spontaneously apply some new auxiliary method or symbol that they then incorporate into their operations.” That kind of approach requires an analysis of the children’s situated meaning-making processes and their consequences throughout the interaction trajectory. It requires an attention
to the children’s interaction that is oriented to observing and analyzing the sense making that is involved in creative, unanticipated collaborative accomplishments. It involves the unique trajectories of student groups, which cannot be coded and statistically aggregated or sorted into standardized categories.

Vygotsky (1930/1978) outlines an intersubjective conception of the development of human cognition and collaborative learning, which treats the interaction, development and learning of groups with artifacts in the shared world as foundational. We shall see a concrete example of this approach toward the end of this essay. Ones understanding of oneself, of artifacts (including representations, gestures, signs, symbols, language) and of the meaningful world are constructed primarily and originally intersubjectively, socially and culturally. The individual is a result of subsequent processes of internalization, including the transformation by young children of speech as intersubjective communication into self-talk and then silent verbal rehearsal or thinking.

The Evolution of Intersubjectivity: Tomasello

Tomasello (2014) complements Vygotsky’s dialectical psychology with a corresponding evolutionary anthropology. He offers us a theory of intersubjective intentionality based on an analysis of human evolution and how human intentionality diverged from that of other primates throughout pre-history. Under environmental pressures, humans developed increasingly complex forms of cooperative sociality (see also Seddon 2014). Tomasello describes a two-step evolutionary sequence: joint intentionality followed by collective intentionality. At both of these transitions, a similar process took place. “A change of ecology led to some new forms of collaboration, which required for their coordination some new forms of cooperative communication, and then together these created the possibility that, during ontogeny, individuals could construct through their social interactions with others some new forms of cognitive representation, inference, and self-monitoring for use in their thinking” (p. 31).

Perhaps the first step took place in the context of collaborative foraging. Early human individuals—in response to a changing feeding ecology—began to join other individuals in pairs in pursuit of shared goals, and they jointly attended to situations relevant to their common goals. ³ “Each participant in the

³ Evolutionary development of mirror neurons and increased brain structure on the biological level may have accompanied and facilitated this increased sense of mutuality on the cultural level as a competitive advantage (Gallese & Lakoff 2005), but see also (Hickok 2014).
collaboration had her own individual role and her own individual perspective on the situation as part of the interactive unit” (p. 78). Tomasello highlights this dual-level structure—*simultaneous joint participation and perspectival individuality*—as a defining structure of what he calls joint intentionality. For him, it is foundational for all subsequent manifestations of human shared intentionality. Of course, early humans had always lived in family units and small tribes (like other primates), but now they began to carry out tasks like strategic hunting in small teams as an “interactive unit.”

The second step took place more recently, as agriculture and domestication of animals led to the founding of the first great civilizations. Modern humans became predominantly cultural beings by identifying with their specific cultural group and collectively creating various kinds of cultural conventions, norms and institutions (p. 80). They thus became thoroughly group-minded individuals. Tomasello argues that the development of joint and collective intentionality provided a necessary foundation for the development of human language and culture, which allowed for the escalating evolutionary emergence of modern human cognition and thinking (p. 128). This rapid form of evolution took place through historically transmitted culture (Donald 1991; 2001), rather than as biological adaptation. Increasingly, our individual cognition became mediated by and derivative of group, collective, cultural and now even global cognition.

Intersubjectivity—as the recognition of other people as having the same kinds of comprehension capabilities as we do (so-called “theory of mind”)—involves perspective taking, being able to view from the other person’s position. For instance, to understand what someone says to me, I have to be able to understand the utterance as coming from the other person, as he might have understood it in articulating it. I also have to understand it as having been designed for me to understand it (“recipient design”). So I have to recognize the speaker as someone who understands meaning and can create it, as well as someone who knows how I might understand what he says. This mutual or reciprocal recognition is a precondition for distinctively human communication (e.g., as evolved beyond animal vocal signaling). Intersubjectivity is a foundation for—a condition for the possibility of—modern human interaction (Duranti 2010).

Of course, our understanding of each other is only tentative and partial. There is no possibility of absolute knowledge of other minds or of identity of mental contents, as Husserl and Schutz argued. Shared understanding is, rather, taken-for-granted, not objective. Furthermore, the sharing is generally developed only to the point necessary to maintain communication (Linell 2014). In general, understanding is always partial and pragmatic; I only understand even my own thoughts enough to continue engaging in the current activity that involves those thoughts.
As Heidegger (1927/1996) put it, understanding is an aspect of our being-in-the-world, of situated activity rather than of mental cognition. We understand something as something to the extent necessary for our dealings with it. Accordingly, our shared understanding with other people should be seen as an aspect of our being-there-with-others in the same world. We share understandings because we share one world; and we do so to the extent necessary for our care for things in the world and our concern for other people as part of our existence in the social world (with our background, our plans, our situation).

The discussion of intersubjectivity in twentieth-century philosophy and social-science theory has moved decisively away from the rationalism of Descartes and its focus on the reasoning of an individual mind. We are embodied in a shared world and we understand ourselves, each other and our world through social interaction, gradual cognitive development and cultural transmission. Intersubjectivity can be more than just the confrontation of independent individuals. It can include the collaborative production of joint meaning in a shared world, where the interaction can result in a unity that is more than a simple aggregate of the inputs of the individuals.

The refined conceptions of shared understanding in our intersubjective world that emerge from the preceding review are suggestive for research in CSCW and CSCL. We turn now to examples of empirical studies from these fields.

Intersubjectivity in CSCW

The lead article by Tenenberg, et al. documents an instance of intersubjectivity, in which there is joint attention and mutual recognition. Many of the characterizations of forms of intersubjectivity summarized above can be related to the recorded actions of Hank and Danny, two collaborating programmers, and to the analysis of the data by the article authors.

All of the sources considered above discussed the importance of one person seeing the other and being able to observe that they were attending to the same objects. This was a central theme in the lead article as well. The pair-programming work environment was carefully structured so that the participants could see each other and could track each other’s general gaze. This environment was an interesting hybrid of face-to-face and computer-mediated. In fully online alternative systems discussed in the article, the awareness of joint attention was either supported with specific functionalities or seen to be problematic.
The article explicitly focused on the initial alignment phase of Hank and Danny working together. Consequently, we do not get to observe much of how they subsequently proceed in accomplishing their shared work in a fully intersubjective mode. The data presented gives a glimpse into a very narrow—but critical—slice of the intersubjective experience. As the authors note, Hank and Danny are very much at home in their specific work world and only need to align around the particular task at hand. These programmers are experienced at working together in this paired manner. The physical and technical environment has been carefully set up to support their closely coupled cooperative work, and they move around within it skillfully, without displaying explicitly much of the understanding or practices that contribute to such being-there-with-others.

Paired programming—like intersubjectivity itself—can be viewed in two ways. In one, there is cooperation between two subjectivities, who coordinate their actions and reciprocal understandings of each other in two parallel streams of individual cognition. Excerpts 1 and 2 in the article include division of labor, for instance where Danny will write a list on paper while Hank operates the computer. In this view, one programmer may bring in resources (knowledge, skills, processes, artifacts) that the first does not have, or the second programmer can provide an immediate check on the work accomplished by the first.

In the alternative view, the pair collaborates in a single cognitive process of jointly accomplishing the programming task. For instance, excerpt 3 can be seen as the pair narrowing in on a relevant object together through their joint attention to a list on the screen and their interactive construction of an increasingly narrow focus within that list.

3.1 Danny: ((Just before he starts talking, Danny moves left hand that is holding a pen so that the pen points to a specific item on a dropdown menu on the left monitor))
   I bet you if
3.2 ((at apex of point, with pen tapped on screen))
3.3 ((Hank selects item on list that is four items below Danny’s point, which is highlighted on the display))
3.4 Danny: you (go?) ((starts to withdraw hand))
3.5 Hank: ((Hank uses mouse to move cursor two elements higher on the list))
3.6 Danny: bidoni
3.7 Hank: ((Hank moves up two additional elements on list, stays there))
3.8 Danny: m-t-m black

The article authors first describe the actions of the programmers: “Danny uses physical gestures and speech that complement and complete one another to direct Hank to a specific location. Hank uses the mouse for placing the cursor
preparatory to acting with it, which, in its visibility to Danny takes a role in the ‘conversation’ that the two are having concerning the specific location of the next operation.” Then the authors nicely summarize the interaction as follows: “They thus combine a variety of semiotic resources to give this fragment its orderly, sequential character.” What they call the programmers’ “conversation” (including words, cursor movements, pointing gestures and mutual bodily visibility) is in fact a single, well-ordered achievement. It is irrelevant which programmer introduced which resource. All the resources received their meaning from the unfolding joint process of locating the cursor on a particular font name so that the team could work on that object. The actions of the two programmers form a single orderly sequence.

In the analysis of this work as a collaboration, the two programmers are seen to be checking—or grounding (Clark & Brennan 1991)—their understanding of each other through their utterances, repairs, gestures and gazes. This reciprocal testing of interlocutors’ understandings corresponds to the mutual reciprocity of knowledge in some of the theories of intersubjectivity reviewed above. Certainly, Husserl and Schutz, with their orientation to individual consciousnesses, relied heavily on one subject’s knowledge that the other knows that the first knows that…. Even Tomasello focuses on the recursive recognition of other minds as sentient and perspectival. While Tomasello is persuasive that the evolution of this capability of recursive recognition to arbitrary levels was a necessary evolutionary precondition for modern human cognition and collaboration, that does not mean that we must always engage in some sort of mental recognition that you understand that I understand, etc. There may be occasions when this is indeed necessary, but only then does it actually have to be carried out. Furthermore, we have the ability to respond to questioning by making retroactive statements of mutual recognition to arbitrary levels of recursion. However, this need not enter into most activities of joint understanding. Such mutual recognition is already implicit in the fact of joint understanding. It is taken for granted in Heidegger’s being-there-with-others, in which we care for each other as human, or in Merleau-Ponty’s gaze, in which we see the body of the other as another human perspective on our shared world.

In his recommendations for social-science analysis, Garfinkel (1967) noted that common ground is established by the methodical ways in which things are said, not by a process of verifying agreement of the sets of presumed mental contents stored in the heads of the speaker and of the hearer:

For the conduct of their everyday affairs, persons take for granted that what is said will be made out according to methods that the parties use to make out what they are saying for its clear, consistent, coherent, understandable, or planful character, i.e., as subject to some rule’s
jurisdiction—in a word as rational. To see the “sense” of what is said is to accord to what was said its character “as a rule.” “Shared agreement” refers to various social methods for accomplishing the member’s recognition that something was said-according-to-a-rule and not the demonstrable matching of substantive matters. The appropriate image of a common understanding is therefore an operation rather than a common intersection of overlapping sets. (p. 30)

The authors of the lead article have gone to pains to avoid mentalist explanations. They formulate their discussion of aligning visual fields in terms of the methodical ways of establishing joint attention to a shared object rather than as checking that one subject knows that the other is looking at the object and the other knows that the first knows that, etc. The establishment of joint attention—so necessary for collaboration—entails that the people involved are looking at the same object together. They do not just happen to be individually oriented to the object, but are oriented toward it in a coordinated way. They do not have to be separately aware of the assumed recursive mutuality of this relationship—unless there is some kind of breakdown that needs to be repaired by checking verbally on the mutuality of gaze to some recursive depth. A contribution of the lead article analysis is to explicate the need to support the participants’ operations of maintaining awareness of the mutuality of their joint attention and to describe their methods of doing so in their hybrid environment.

Just as there is an ambiguity to the method of paired programming between cooperation (with division of labor) and collaboration (working together on each step, although possibly from different perspectives or with different resources), so there is an ambiguity to excerpt 3. While we have viewed the interaction there as a single, coherent, meaningful achievement, it could also be viewed in terms of the distinct actions of two individual subjects. One could argue that Danny had himself identified the item in the list on the computer screen from the start by tapping on it with his pen. Then Hank followed Danny’s guiding gestures to eventually recognize the same item by highlighting it with his cursor. This is a pervasive ambiguity in the analysis of CSCW data. To decide in favor of an analysis that treats the group as the primary agent or one that focuses on the contributions of individuals generally requires detailed interactional data, which is rarely available to researchers. For instance, if excerpt 3 did not include Danny’s bodily gestures and Hank’s computer actions in addition to the spoken discourse, it would be impossible to analyze the identification of the font as a joint achievement.

The alignment phase involves a transition from individual cognition to intersubjective cognition. It therefore contains elements of each and can be analyzed at either the individual or group unit of analysis. At the individual level,
it appears that subjects are monitoring each other’s gaze or focus of attention. Here is where the reciprocal and recursive recognition come in and the conception of communicative signals being exchanged. Especially in the case of dyads, it is tempting to analyze individual intentionality and agency in a traditional, individualistic way; in somewhat larger groups, the interaction is often harder to attribute to individuals as the discussion builds on individual utterances in complex ways and takes turns that no one participant planned. At the group level of description, the group is beginning to act as a unity, creating social order and joint meaning in a shared world—not through independent acts of the individual participants, but through the interaction of the group.

The ambiguity is important. The point is not so much to always opt for an individual or a group focus, but to recognize their intertwining: that the individual is a social product, but also that the intersubjective has the individual at its poles. Sometimes one unit of analysis is more useful than the other. Efforts at alignment, in particular, involve a transition from multiple individual cognitions to a unified group cognition. Philosophies of dialogicality have long tried to maintain this balance of what Tomasello calls joint intentionality with individual perspectives, which is not well supported by our inherited conceptualizations (Rommetveit 2003; Wertsch 1991). Interaction analysis—as carried out in the lead article—has shown us how to analyze the displayed utterances of individuals as part of intersubjective processes of group meaning making and social-order construction, without hypothesizing hidden mental phenomena (Schegloff 1991).

To understand we-awareness or intersubjectivity once a team has come into alignment and is working smoothly together, it would be useful to analyze excerpts of interaction in later phases with the same kind of detail provided for the alignment phase in the lead article. Fuller examples of completely online group work would also be relevant to CSCW. The authors note a paucity of appropriate, detailed data about computer-mediated CSCW interactions on work like paired programming using different mediating technologies. In addition, we might add, there is little data reported about how people first learn to interact skillfully within such contexts. For a suggestion of how intersubjectivity might be analyzed and supported in more contexts, we turn to CSCL.

Intersubjectivity in CSCL

The relation of CSCW to CSCL has not been widely noted or clearly articulated. Both involve computer support for people interacting. While CSCW has the advantage of studying people who are expert at their work and experienced at
working together, CSCL has the advantage of observing how such expertise and such interaction between people is originally constituted and learned. CSCL education can prepare students for careers in CSCW workplaces, and CSCW can display domain-related practices for adoption in CSCL curricula. The two fields share an interest in how individual and intersubjective cognition complement each other and how computer-support artifacts or environments mediate between them.

This section of the essay will review a specific research agenda that explored the nature of intersubjectivity in a variety of small-group math-education settings. It will present examples of intersubjective knowledge building under several diverse, but typical learning conditions, involving computer mediation.

Based on research in CSCW and CSCL, Stahl (2006a) proposed a form of intersubjectivity called group cognition. Group cognition can be thought of as a form of intersubjectivity that goes beyond the mutual recognition of individual minds in Husserl and the recursive thou-relationship of Schutz to a being-there-with-others that Heidegger and Merleau-Ponty briefly hint at. Its analysis is based on the social-historical-cultural approach of Hegel, Marx and Vygotsky. It is a developed form of Tomasello’s joint intentionality with individual perspectives. Group cognition is a vision of intersubjectivity for CSCW and CSCL, which goes beyond the accomplishments of individual cognition within group efforts.

In group cognition, multiple people participate in coherent interactions that achieve cognitive accomplishments that are best analyzed at least in part at the group unit, rather than attributing contributions and agency entirely to individual minds. When a number of people are involved in group-cognitive processes or activities, their individual utterances or actions are taken as merged in a single cognitive system, which is distributed across the people and the artifacts that are involved (Hutchins 1996). Ideas, practices, habits and traditions from the larger culture are also brought in, so that the group cognition mediates between individual and community units of analysis (Stahl 2013e, Ch. 8).

The original elaboration of the notion of group cognition arose within a series of studies of software environments to support perspectives, negotiation and group formation in specific workplace and school settings (Stahl 2006a, e.g., Ch. 3, 6, 8). It provided, for instance, a detailed example of group cognition, in which a face-to-face student group co-constructed the meaning of a scientific representational artifact in an educational computer simulation in 1998 (Ch. 12 & 13). However, the collection of studies also acknowledged that the vision of group cognition as an effective form of collaborative learning is rarely achieved in practice. Furthermore, it noted the difficulty of finding or collecting data that
is adequate for establishing and analyzing group cognition, let alone for observing the mediation across levels of analysis.

Later (from 2002-2015), the Virtual Math Teams (VMT) system was developed as a test ground for studying group cognition. VMT is a collaboration environment for mathematical problem solving by online small groups of students. Reports on pedagogical and methodological issues in VMT (Stahl 2009) included analysis of a text chat in which several online students solved a challenging word problem collaboratively that none could solve individually (Ch. 5). The analysis argued that their chat could be viewed as a group-cognitive accomplishment, integrating a chain of interactive responses similar to a solution that could have been stated by one person but here involving the whole group as the problem-solving agent. Another case study (Ch. 7) discussed how three students working online in VMT with a shared graphics whiteboard maintained joint attention to geometric details and organized their graphical, symbolic and narrative interactions to solve an intricate problem in combinatorics collaboratively.

More recently, the VMT environment was extended with a custom multi-user version of GeoGebra, an application for dynamic geometry. A stimulating problem often given to people once they become comfortable with dynamic geometry is that of constructing inscribed triangles that behave like a given pair of inscribed triangles. (See the instructions and inscribed triangles ABC/DEF in Figure 1.)
Figure 1. The state of the inscribed-triangles construction after Fruitloops finished triangle KMR inscribed in GHI.

This is a difficult task even for adults who enjoy mathematics. The VMT research team has been looking closely at the logs of a group of three 14-year-old girls who succeeded with this problem in less than an hour. None of the students had studied geometry before joining an after-school math club as part of our research project; they had spent four hours working together on collaborative dynamic geometry before this session.

The analysis of the team’s work concluded that the students’ success was an instance of group cognition (Stahl 2013e, Ch. 7.3). None of the students could construct the triangle configuration themselves and the process of construction involved all three exploring, planning and carrying out the construction. Each of the three girls displays a different characteristic behavior pattern throughout their work in the eight hour-long sessions of our study. Yet, the team is impressively collaborative. This illustrates nicely the notion of individual perspectives within intersubjective group interaction.

What was particularly striking in the team’s successful construction of the inscribed triangles was that on first appearance it seemed like the team’s insightful and skilled work was actually done primarily by the student who until then had seemed the least insightful and skilled. If one just looks at the chat postings (see panel in the right side of Figure 1), Cheerios does all the talking and Fruitloops (who is usually the most reflective and insightful) and Cornflakes (who explores the technology and often shows the others how to create
geometric objects) simply register passive agreement. However, the actual GeoGebra construction actions tell a far more nuanced story. First, for almost an hour each of the three students in the “Cereal Team” took extended turns exploring the given example of inscribed triangles by dragging the vertices to discover dependencies in the construction that dynamically maintained the invariances of equilateral triangles. The dragging of figures is displayed simultaneously on each student’s computer. Only one person at a time can create or drag geometric objects, in order to maintain joint attention by everyone to a single, shared sequence of actions.

Cheerios observes Fruitloops experimenting with the use of the GeoGebra compass tool just before Cheerios takes control and makes her discovery. Cheerios continues to manipulate Fruitloops’ construction, involving a circle whose radius was constructed with the compass tool to be dependent on the length of a line segment. Then Cheerios very carefully drags points on the original inscribed-triangle figure to discover how segments BE and CF are dependent upon the length of segment AD, refining prior movements by the other students. The dynamic relationship between the side lengths becomes visually salient as she increases the size of the triangles or their orientation and as she drags point D along side AC.

Cheerios has a sense that the compass tool should be used to measure segment KG, but she does not quite understand how to make use of that tool. Following Fruitloops’ example, Cheerios uses the compass to draw a circle around point I, whose radius equals length GK (see Figure 2, left). However, she is unable to further implement the plan she has already projected in chat.

Next, Cornflakes takes control of the construction, places a point, M, where Cheerios’ circle intersects side HI and then repeats the process with the compass to construct another point, R, on the third side of the exterior triangle (see Figure 2, right).
Fruitloops then takes control and uses the polygon tool to construct a shaded interior triangle, KMR, connecting Cornflakes’ three points on the sides of the exterior triangle (see Figure 1). She then conducts a drag test, dragging points on each of the new triangles to confirm that they remain equilateral and inscribed dynamically, just like the example figure. At that point, the students have been working in the room for over an hour and end their session, having succeeded as a team.

The VMT software is fully instrumented, so that researchers can obtain detailed logs and even replay the sessions (as shown in Figure 1, a screen image from the replayer) to see precisely what the students all saw on their screens. Of course, as Schutz pointed out, researchers have a reflective relationship to the interaction, which is quite different from the engagement of the students. The intersubjectivity of the students, when things are functioning optimally, can be that of group cognition, where they act as one subject, constructing shared meaning through their interaction. The intersubjectivity of the researchers with the students involves systematic (methodical, self-conscious, research-driven, theory-laden) efforts to understand the meanings previously created by the students, based on a culture and world partially shared by the researchers.

Intersubjectivity as Group Cognition

The kind of data generated by teams of students using VMT can support detailed research into the nature of interaction and intersubjectivity in CSCW and CSCL situations. For instance, the VMT research team has now analyzed all eight hours of the Cereal Team’s interaction (Stahl 2015b). In particular, we
track their enactment and acquisition of various member methods or group practices. We see how the students form into an effective team and how they align and develop joint attention. By adopting specific sequences of group practices, the team learns how to collaborate, to manipulate technological affordances, to engage in collaborative dynamic-geometry problem solving and to enter into mathematical discourse. Displayed in the team interaction, we can see group cognition in action as a specific form of intersubjectivity.

We see the potential productivity of collaboration in the way that the three students, participating from within their personal zones of proximal development, bring different resources to the interaction. Further, the interaction itself elicits—as Merleau-Ponty put it—“thoughts which I had no idea I possessed.” Ideas, skills and approaches from different sources mix and spontaneously generate new, shared knowledge through the interaction itself and its internal logic or implicit connotations. Collaborative learning may be guided through reflection by the participants and through feedback from the problem-solving process itself. For instance, observation of the results of various people’s attempts at geometric manipulations and constructions may lead to the discovery of solutions that cannot be attributed to any one of the participant’s minds or even to a simple aggregation of their individual contributions. The dynamic behavior of their joint geometric-construction moves in their shared online world contributes to the unfolding of a solution path as well.

In the Cereal Team’s work, we see multiple instances of one student contributing a skill or insight from their individual perspective or developmental zone into the group work—usually in response to what another student did or tried to do. The other students learn from this—often from just one occurrence, where the contribution is discussed and consequently adopted by the team as a group practice. Subsequently, another student brings the newly learned skill into the group work, and it is accepted without comment. In this way, first, the group learns a skill or insight and through that, each of the other individuals learns it. For instance, in the session just described, it took each of the three students doing some of the necessary actions to construct the inscribed triangles. However, in their next session, all three students very clearly knew how to carry out all those actions when the group worked on a related challenge of constructing inscribed squares.

In the longitudinal developmental trajectory of the Cereal Team (followed in detail in Stahl 2015b), as the team first learns to collaborate online and to engage in dynamic geometry, we can observe the reciprocal interpenetration of individual and collective understanding in the group-cognition form of intersubjectivity. We see what our review of theories of intersubjectivity characterized as simultaneous joint participation and perspectival individuality, as
well as joint attention, shared meaning making, group agency and being-there-with-others in a shared world.

The Cereal Team took up in their discourse mathematical terms like “constraint” and “dependency,” which were introduced in their session instructions. The choice of classical geometry problems and the wording of their presentation to the students guided the student exploration and discourse, mediating the interaction with resources from the mathematical community. By responding to the cues in the instructions and incorporating these technical terms in their discourse with each other, the students gradually developed new conceptions. At first not understanding the terms at all, they passed through everyday uses of them to more rigorous mathematical statements—in a process recalling Vygotsky (1934/1986). The transitions in individual and group understanding of the role of dependencies in dynamic geometry can be tracked in the logs of their interaction (Stahl 2015b).

While all the reviewed theories of intersubjectivity noted the important role of language, Vygotsky was especially clear about the mediation of language—both spoken and thought—in how we understand each other and our shared world. Heidegger’s later work (e.g., 1959/1971) also emphasized how language can be seen as a source of meaning making—most visibly in poetry. For him, “speech speaks” (through us) and we live in language as the “house of being.” As Tomasello (2014) notes, the cultural richness of spoken languages incorporates eons of human shared experiences. In the mixing pot of group discourse, phrases evoke each other and thereby generate creative ideas.

Of course, competent language users are needed to speak and understand the phrases. However, the source of the creative generation and the deductive flow can be analyzed in terms of the meanings sedimented in the phrases, rather than being attributed to rational motives in the minds of individual participants. Group cognition and its associated intersubjectivity can be conceived in primarily linguistic, rather than mental, terms (as recommended by Habermas 1971/2001). Its intentionality is not that of some kind of group mind or even primarily of the minds of the individual participants, but of the intersubjectively shared discourse and the historically mediated referred intentionality of a culture, expressed in its passed-down meanings. That is why a goal of math education is to involve students in math discourse and collaborative exploration.

Group cognition is a form of intersubjectivity, in which the words and actions of group members are aligned in a coherent unity, which can be analyzed as a semantic (meaning-making) or cognitive (symbol-manipulating) system in its own right. This vision of a potentially powerful form of group intersubjectivity can inspire and guide the design of supportive technology and pedagogy in CSCW and CSCL, as it has done in the VMT project (Stahl 2006a; 2009; 2013e; 2015b).
The Constitution of Group Cognition

Abstract: Cognition is no longer confined to the solitary musings of an armchair philosopher, but takes place, for instance, in problem-solving efforts of teams of people distributed around the world and involving various artifacts. The study of such cognition can unfold at multiple units of analysis. Here, three cases of problem solving by virtual math teams demonstrate the mix of individual, group and social levels of cognition. They show how a resource like a mathematical topic can bridge the different levels. Focusing on the under-researched phenomena of group cognition, the presentation highlights three pre-conditions for the constitution of group cognition: longer sequences of responses, persistent co-attention and shared understanding. Together, these structure a virtual analog of physical embodiment: being-there-together, where what is there is understood as co-experienced.

Cognition at Multiple Levels

There is a venerable tradition in philosophy that cognition is a mysterious faculty of individual human beings. Increasingly since the late nineteenth century, it has become clear that even when thoughts appear to be expressed by an individual they are the product of more complex factors. Cognitive abilities and perspectives develop over time through one’s embeddedness in a physical, social, cultural and historical world. Thinking is closely related to speaking, a form of communication with others. Particularly in our technological world, thinking is mediated by a broad variety of artifacts and by other features of the context in which we are situated.
Rather than thinking about thinking, I try to explore cognition by generating data in which one can observe cognitive processes at work (Stahl, 2006; 2009; 2013). I do this by having small groups of students collaborate on mathematical problems in a setting where their whole interaction can be captured. The motivation for this approach is the theory of Vygotsky, the sociocultural psychologist who proposed that higher-level human mental abilities are acquired first in small-group interactions. In exploring such group cognition, I have found that there is a rich interplay of processes at individual, small-group and community levels of cognitive processing.

In the following, I will summarize three case studies in order to illustrate how cognitive processes at multiple levels can work together. In the first case, two students solve a high-school math problem that has stumped them for some time. The problem-solving steps the dyad go through as a team are typical for how proficient students solve problems individually. In the discourse captured in this case, one can see how the group integrates contributions from the two individual participants to accomplish a task in accordance with community standards of practice—illustrating the productive interplay of cognitive levels. The sequence of ten discourse moves by the group details their extended sequential approach to the problem. In the second study, three students develop techniques for helping each other to see what they are seeing in the diagram they have drawn for a math problem. This persistent co-attention to a shared object of analysis allows the team to solve their problem as a group. Similarly in the third example, the students are able to work together because they effectively manage their shared understanding of the problem.

I propose that it is often fruitful to analyze cognition on multiple levels and that the processes at the different levels work together. A variety of interactional resources are typically at work bridging the levels. In the three illustrative case studies, topics in high-school mathematics centrally figure as resources that bring together individual, small-group and community cognitive processes.

Virtual Math Teams

The study of group cognition requires careful review and analysis of all the interaction within a group during the achievement of a cognitively significant task, such as solving a challenging problem. I have arranged for this by designing an online software environment in which several people can meet and interact effectively to solve math problems. This Virtual Math Teams (VMT) environment supports synchronous text chat and a shared whiteboard for drawing figures (Stahl, 2009). Recently, it has been expanded to incorporate a
multi-user version of dynamic geometry, in which geometric figures can be interactively constructed and dynamically dragged (Stahl, 2013). The software is instrumented to capture all interaction and to allow it to be displayed, replayed and analyzed. This avoids the many difficulties of audio and video recording in classrooms. Students communicate online, avoiding the interpretational issues of eye gaze, bodily gesture and vocal intonation. When possible, groups are composed of students who do not know each other outside of the online setting, so that researchers reviewing a record of interaction can know everything about the participants and their background knowledge that the participants know about each other. Since group cognition is defined as consisting of those knowledge-building or problem-solving processes that take place in the group interaction (Stahl, 2006), the VMT environment can capture a complete history of group-cognitive events.

When a group enters the VMT environment, it is presented with a challenging math problem, designed to guide the group interaction in an academically productive direction. The problem acts as a resource for the group. The group must interpret the problem statement, elaborate the way in which it wants to conceive the problem and determine how to proceed. A math problem can serve as an effective interactional resource for bridging across cognitive levels. Typically, it introduces content—definitions, elements, procedures, principles, practices, proposals, theorems, questions—from the cultural traditions of mathematics and from school curriculum. In so doing, it recalls or stimulates individual cognitive responses—memories, skills, knowledge, calculations, deductions. It is then up to the group interaction to bring these together, to organize the individual contributions as they unfold in the ongoing interaction in order to achieve the goals called for by the community, institutional, disciplinary and historical sources. In this way, the group interaction may play a central role in the multilevel cognition, interpreting, enacting and integrating elements from the other levels, producing a unified cognitive result and thereby providing a model for future community practice or individual skill.

It may seem ironic that an online environment has been selected for the empirical study of how cognition is “embodied” in group interactions and community contexts. In the VMT environment, participants are not physically present to each other. They do not see interactional contributions being produced by individuals. Rather, text chat postings suddenly appear as complete units on the screen and geometric elements are drawn or dragged without visible hands manipulating them. As we will see below, Aznx does not see how Bwang is gradually putting together and occasionally repairing a sentence to be posted. Jason cannot follow Qwertyuiop’s gaze to see where his attention is focused. Yet, there are some elements of embodiment, at least virtually. Each participant is represented in the VMT interface with a login handle, associated with their chat postings. There are awareness notices indicating who is typing a pending
chat contribution or who is engaged in a geometric construction action. The software interface presents a complexly structured visual manifold. Students quickly develop online practices to adapt to the new environment, to overcome the limitations of the media and to implement alternative means for missing abilities, as seen in the following case studies. Within this computer-mediated context, individual and group levels of cognition are focused on situated entities from specific perspectives; multilevel cognition is embodied in an intersubjective world.

### Constructing Diamonds

Cognition is neither a unitary phenomenon nor a temporally fixed one. Hegel described the logical stages involved in the development of cognition in his *Phenomenology of Mind* (1807/1967). Vygotsky explored the development of a person’s cognition through psychological experiments reported in *Mind in Society* (1930/1978), emphasizing the priority of intersubjective group cognition:

> Every function in the child’s cultural development appears twice: first, on the social level, and later, on the individual level; first, between people (*interpsychological*), and then inside the child (*intrapsychological*). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher [human mental] functions originate as actual relations between human individuals. (p. 57, emphasis in original)

Research on computer-supported collaborative learning (CSCL) (Stahl, Koschmann & Suthers, 2013) can make visible the development and the unfolding of cognitive functions in small groups, shedding light on the less-visible processes that can subsequently be carried out by people individually or “internally.” A research method for undertaking such analysis is suggested by the field of conversation analysis (CA) (Sacks, 1962/1995). CA was inspired by ethnomethodology, a sociological approach focused on describing the “work” that people typically do in interactions with others to establish social order and to construct meaning (Garfinkel, 1967). CA applies this approach to analyzing everyday conversation. A central finding of CA is that the work of conversation is accomplished through the sequential construction of “adjacency pairs,” short sequences in which one person’s utterance elicits a response in the form of a following utterance by an interlocutor—for instance a question-answer pair. In looking for examples of mathematical problem solving by groups, we are more interested in “longer sequences,” in which a series of adjacency pairs are constructed to accomplish the larger cognitive goal.
Longer sequences have only been suggested in CA (Sacks, 1962/1995, Vol. 2, p. 354; Schegloff, 2007, pp. 12, 213), not extensively analyzed. In the final excerpt from a VMT interaction among three students, I analyzed their successful problem-solving effort as a longer sequence, consisting of ten discourse moves, each linguistically organized as an adjacency pair (Stahl, 2011). I treated their four-hour-long online interaction in terms of a temporal hierarchy of: a group event, four scheduled sessions, several conversational topics, many discourse moves, adjacency pairs, textual utterances and indexical references. In the first session, the students had been asked to work on a topic in mathematical combinatorics, determining the number of squares and composite sticks needed to build a stair-step pattern at different stages of growth. By the fourth session, the students had set themselves the topic of analyzing a diamond pattern, illustrated by them at stages n=2 and n=3 in the screen image of the VMT software interface in Figure 1.

Figure 1. Discussion and drawings of diamond pattern.

In their final conversational topic, two students with login names of Bwang and Aznx decide to try again to solve this problem, despite not being able to do so for the past two hours and despite the fact that their scheduled online time is already over. In the course of ten minutes, 100 chat lines of text are posted. The analysis highlights ten adjacency pairs that were central to this discourse. Each adjacency pair is listed in Log 1, under an added descriptive heading. Although there is not space here to provide the full chat or a complete analysis, this selection from the interaction should give a sense of the problem-solving process.
Move 1. Open the topic

Bwang: I think we are very close to solving the problem here
Aznx: We can solve on that topic.

Move 2. Decide to start

Bwang: Well do you want to solve the problem
Aznx: Alright.

Move 3. Pick an approach

Aznx: How do you want to approach it?
Bwang: 1st level have 1*4 ... 4th level have (1+3+5+7)*4

Move 4. Identify the pattern

Aznx: So it’s a pattern of +2s?
Bwang: yes

Move 5. Seek the equation

Bwang: What is it
Aznx: n^2 ... or (n/2)^2

Move 6. Negotiate the solution

Aznx: its n^2
Bwang: so that’s wrong

Move 7. Check cases

Aznx: would be 4n^2
Bwang: it actually is

Move 8. Celebrate the solution

Bwang: I think we got it!!!!!!!!!!!
Aznx: WE DID IT!!!!!

Move 9. Present a formal solution

Aznx: So you’re putting it in the wiki, right?
Bwang: yes

Move 10. Close

Aznx: we should keep in touch
Bwang: yeah

Log 1. Ten moves of the problem-solving topic.

There are several things to note here:
Most importantly, the sequence of moves is strikingly similar to how an experienced math problem solver might approach the topic individually, as described at a particular granularity.

The two students take turns contributing to the shared topic. The group direction is not set by either individual, but results from their interaction.

Most opening utterances solicit a response, often in the explicit form of a question, and they always await a response.

Each move is a situated response to the current state of the students’ understanding of the topic as expressed in the discourse—rather than some kind of logical progression following a plan based on some kind of goal-subgoal hierarchy (Suchman, 2007).

The focus of the group discourse moves is on the sharing, negotiation and agreement about their progress, rather than on details of mathematical facts or computations.

The math content is handled by the individuals and contributed by them into the collaborative setting, for instance in move #3 or #5.

The temporal structure of topics, moves and adjacency pairs is not imposed by the analyst, but is projected in the remarks of the participants as integral to how they make meaning for themselves about what they are doing.

If one follows the development of the students’ understanding in their postings across the four sessions, one is struck by changing roles and confidence levels, as well as by their mastery of practices that one or the other introduced into the group. It is quite plausible that over time the lessons acquired in their collaborative interactions become manifested in their individual cognitive skills. The longer sequences of argumentation or problem solving become “internalized” (as Vygotsky called it) or adopted as cognitive practices of individuals. The power of collaborative learning is partially to bring together multiple perspectives, which can be debated, negotiated, synthesized, contextualized, structured and refined. However, another advantage is to extend the cognitive effort into longer sequences of argumentation through the stimulation and enjoyment of productive social interaction, increasing the time-on-task as needed to solve challenging problems. Thus, groups can achieve cognitive accomplishments that their members cannot—and the members can learn from these achievements.
Visualizing Hexagons

Elsewhere, we have analyzed in some detail the intimate coordination of visual, narrative and symbolic activity involving the text-chat and shared whiteboard in VMT sessions (Çakir & Stahl, 2013; Çakir, Zemel & Stahl, 2009). Here, we want to bring out the importance of literally looking at some mathematical object together in order to share the visual experience and to relate to—to intend or to “be at”—the entity together. People often use the expression “I do not see what you mean” in the metaphorical sense of not understanding what someone else is saying. In our second case study, we often encounter the expression used literally for not being able to visually perceive a graphical object, at least not being able to see it in the way that the speaker apparently sees it.

While empiricist philosophy refers to people taking in uninterpreted sense data much like arrays of computer pixels, post-cognitive philosophy emphasizes the phenomenon of “seeing as.” Wittgenstein noted that one immediately sees a wire-frame drawing of a cube not as a set of lines, but as a cube oriented either one way or another (1953: §177). For Heidegger, seeing things as already meaningful is not the result of cognitive interpretation, but the precondition of being able to explicate that meaning further in understanding (1927/1996, p. 139f.). For collaborative problem solving and mathematical deduction, it is clearly important that the participants see the visual mathematical objects as the same, in the same way. This seems to be an issue repeatedly in the online session excerpted in Log 2, involving three high-school students with login handles of Jason, Qwertyuiop and 137 (Stahl et al., 2011).

<table>
<thead>
<tr>
<th>705</th>
<th>19:15:08</th>
<th>137</th>
<th>So do you want to first calculate the number of triangles in a hexagonal array?</th>
</tr>
</thead>
<tbody>
<tr>
<td>706</td>
<td>19:15:45</td>
<td>Qwertyuiop</td>
<td>What's the shape of the array? a hexagon?</td>
</tr>
<tr>
<td>707</td>
<td>19:16:02</td>
<td>137</td>
<td>Ya.</td>
</tr>
<tr>
<td>708</td>
<td>19:16:15</td>
<td>Qwertyuiop</td>
<td>ok...</td>
</tr>
<tr>
<td>709</td>
<td>19:16:41</td>
<td>Jason</td>
<td>wait-- can someone highlight the hexagonal array on the diagram? i don't really see what you mean...</td>
</tr>
<tr>
<td>710</td>
<td>19:17:30</td>
<td>Jason</td>
<td>hmm.. okay</td>
</tr>
<tr>
<td>711</td>
<td>19:17:43</td>
<td>Qwertyuiop</td>
<td>oops</td>
</tr>
<tr>
<td>712</td>
<td>19:17:44</td>
<td>Jason</td>
<td>so it has at least 6 triangles?</td>
</tr>
<tr>
<td>713</td>
<td>19:17:58</td>
<td>Jason</td>
<td>in this, for instance</td>
</tr>
</tbody>
</table>

Log 2. Seeing a hexagonal array collaboratively.
Student 137 proposes a mathematical task for the group in line 705 of Log 2. This is the first time that the term, “hexagonal array,” has been used. Coined in this posting, the term will become sedimented (Husserl, 1936/1989: 164) as a mathematical object for the group as the discourse continues. However, at this point it is problematic for both Qwertyuiop and Jason. In line 706, Qwertyuiop poses a question for clarification and receives an affirmative, but minimal, response. Jason, unsatisfied with the response, escalates the clarification request by asking for help in seeing the diagram in the whiteboard as a “hexagonal array,” so he can see it as 137 sees it. Between Jason’s request in line 709 and acceptance in line 710, Qwertyuiop and 137 work together to add lines outlining a large hexagon in the triangular array. Demonstrating his ability to now see the hexagons, Jason thereupon proceeds with the mathematical work, which he had halted in the beginning of line 709 in order to keep the group aligned. Jason tentatively proposes that every hexagon “has at least 6 triangles” and he makes this visible to everyone by pointing to an illustrative small hexagon from the chat posting, using the VMT graphical pointing tool. Later, the students take turns using these group-defined methods of supporting shared vision and attention: using colored lines and the pointing tool, as seen in Figure 2.

Jason dramatically halted group work with his “wait.” For him, it was impossible to continue until everyone could see the same thing in the way that 137 saw it. During this session, the students taught each other how to change the color and thickness of lines they constructed in the shared whiteboard. These were affordances of the VMT software, but the students had to learn how to use the features and they developed certain shared group practices of using colored lines to outline, highlight and draw attention to specific elements of the hexagonal grid. For instance, in Figure 2, blue lines outline a hexagon of side length 3; red lines divide that hexagon into six symmetric triangles; thick green lines pick out the three horizontal lines of length 1, 2 and 3 in one of the triangles; and the VMT pointing tool focuses attention on that triangle. There are many ways to count the number of unit sticks in the large hexagon. In order to count them as a group, everyone’s attention must be focused on the same elements, such as the green horizontals. Then it is possible for each participant to count that subset visually: 1+2+3=6. Through similar shared attention to structural elements of the hexagon, all the group members know that there are three such arrays of lines like the green ones at different orientations in each of the six triangles. They can also see how this array of lines will increase as the hexagon itself progresses to successively longer side lengths. The achievement of the necessary persistent co-attention to construct and to follow this complicated analysis was the result of subtle interactions and the development of shared practices within the group.
Inscribing Triangles

Our final case involves a group of three middle-school students given a topic in dynamic geometry (Stahl, 2013, §7.3). The students have not yet had a course in geometry, but have already spent four hours together in a version of VMT that incorporates interactive, multi-user support for dynamic geometry. In this topic, the students are given constructions of an equilateral triangle inscribed inside another equilateral triangle and a square inscribed inside another square (see Figure 3). In dynamic geometry, a student can drag one point of a figure like the inscribed squares and all the other points and lines will move accordingly, maintaining the geometric relationships or dependencies that have been built into the construction of the figure. In previous sessions, the students had learned the dynamic-geometry equivalent of Euclid’s first two propositions: the construction of an equilateral triangle (using software tools equivalent to a straight edge and compass) and the copying of a line-segment length.

In their fifth session, the three students took turns dragging points of the equilateral triangles and discussing the dependencies that were maintained. Then they tried to duplicate the given figure and to build in the relevant dependencies. For instance, the dependency defining the equilateral character of the outer triangle is that the lengths of the second and third sides must always be the same.
as the length of the base, even when the end points of the base segment are dragged, changing its length. Euclid’s construction maintains this dependency because the lengths of all three sides are radii of circles of equal radius. Read today, Euclid’s *Elements* (300 BCE/2002) in effect provides instructions for dynamic-geometry constructions. The “elements” of geometry are not so much the points, lines, circles, triangles and quadrilaterals, but the basic operations of constructing figures with important relationships, such as congruence or symmetry. Just as Euclidean geometry contributed significantly to the development of logical, deductive, apodictic cognition in Western thought and in the formative minds of many prospective mathematicians, so collaborative experiences with dynamic geometry may foster in students ways of thinking about dependencies in the world.

![Figure 3. Discussion and constructions of inscribed squares.](image)

The students in the case study used Euclid’s method to construct the outside triangle, but soon realized that the same procedure could not be used to construct the inscribed triangle, because of the additional constraint that its vertices all had to be on the sides of the inscribing triangle, which they had constructed. Considerable further dragging of points in the given figure and experimentation with various construction approaches were tried. Finally, the students noticed that when one point of the inner triangle was dragged along a side of the outer triangle, the other vertices of the inner triangle moved in a corresponding way, such that their positions along their sides of the outer triangle were the same as that of the dragged vertex on its side. Then they quickly decided to use the method they had learned for copying a line-segment
length. They copied the length from one outer vertex of their new equilateral triangle to a point for an inner vertex. Then they placed this length along the other sides, starting at both of the other vertices. This determined the locations of the other inner vertices. When they connected the three points, they formed an inscribed triangle. When any point or line was dragged, both the inner and outer triangles remained equilateral and inscribed.

In their sixth session, the students tackled the topic of inscribed squares. All their previous work in dynamic geometry had involved triangles and they had not been exposed to a method of constructing a dynamic square. They spent most of the hour exploring possible construction methods, eventually inventing a method that was elegantly similar to that of the triangle construction. All three students then immediately saw how to construct the interior square by copying the length from a corner of the exterior square to a corner of the interior one along a side. In Figure 3, the circles used for copying the length are still visible. The clarity with which each of the students understood how to inscribe a square—one they were able to construct the exterior dynamic square—shows how well they had each individually mastered the technique from their prior collaborative experience involving the dynamic triangles.

Their collaborative solution of the inscribed-triangles topic is quite typical. We have observed a number of small groups working on this topic, including math teachers, researchers, graduate students and middle-school students. They all go through a similar process of dragging the original figure, experimenting with construction attempts, discovering the dependency of the distances between the interior and exterior vertices, then realizing how to copy that distance and finally checking that their construction has the same behavior as the given figure. While this topic poses a problem that is difficult for individuals, small groups tend to stick with it and sometimes solve it through collaborative effort within an hour or less. It takes a combination of many trials, observations and connections to accomplish the task. The collaborative approach allows individuals to contribute specific pieces of the puzzle, to build on each other’s proposals and to discuss the implications.

The chat discourse is striking in how much the students make sure that everyone agrees with and understands each step that the group as a whole takes in constructing their figures. In addition to expressing agreement and affirming understanding, the students also demonstrate their shared understanding by fluidly building on each other’s contributions. Successive steps are generally taken by different students, indicating that they are all following the logic of the collaborative effort.
Contributing to Group Cognition

The cognition in group cognition is not the same as individual cognition; it relies upon individual cognition to make essential contributions. However, one cannot say that all of the cognition should be analyzed at the individual unit, because the work of assembling the high-level argumentative structure occurs at the group unit of analysis. Surely, putting together problem-solving arguments must be considered a cognitive activity as much as the work that goes into making the detailed contributions to individual steps. In addition, the personal contributions are largely responses to what has gone before in the group interaction. Not only are these contributions expressions that would not have occurred without the preceding opening up for them and elicitation of them by the group process, but many of the contributions are largely reactions at the group level, which reference and interrelate resources available in the discourse context more than they introduce new elements from the personal perspective and individual background of the actor. The important cognitive achievement is emergent at the group level, rather than a simple collection of expressions of individual cognitive accomplishments.

Coherent and impressive examples of group cognition—such as solving a math problem that the group members would not have been able to solve on their own—do not automatically occur whenever a number of people come together in conversation. In fact, the research field of computer-supported collaborative learning has documented that desirable forms of collaborative knowledge building are hard to find. The three studies summarized above indicate some reasons for this. First, it is difficult to set up a group interaction where everything relevant to the cognition at the group level of analysis is captured in a form adequate for detailed analysis. It took years of research to develop and deploy the VMT environment to successfully generate adequate data for the analysis of group cognition. Secondly, the group interaction must be directed and guided to focus on an appropriate cognitive task. Certain challenging math problems, carefully presented, seem to provide effective resources for stimulating interesting episodes of group cognition. Additionally—as the three studies summarized here have documented—the groups must work consistently to ensure the presence of certain preconditions of effective group cognition. They must persist in building longer sequences of responses to each other, they must maintain continuous co-attention to a shared focus of discussion and they must build and sustain a shared understanding of the topic of conversation.
The Constitution of Group Cognition

The phenomenological tradition has always conceived of cognition as embodied in the world, rather than as a Cartesian mental process. Husserl (1929/1960: §14) emphasized that cognition is cognition of something; it is located at its object, not at some internal representation of that external object. Heidegger (1927/1996) therefore started from the experience of being-in-the-world instead of thinking-in-the-head. For him, cognition is a matter of being-with and caring-for things and people. The world is a shared world and the things we are there with are always already understood as meaningful. In Merleau-Ponty’s (1945/2002) famous example of the blind man with the cane, the cane does not so much augment or extend the man’s senses and awareness of external reality as it locates his cognition in the world at the tip of the cane.

If we look at the presented examples of group cognition, we see that the students are “there” in their group interaction with mathematical objects, seen in specific ways. Aznx and Bwang have drawn the horizontal sticks and the vertical sticks separately (not shown in the summary above). They have noticed a four-way symmetry, which allows them to reduce the problem of counting the sticks to a tractable pattern. They are focused together on the diamond as that symmetric pattern of sticks. Similarly, Jason, Qwertyuiop and 137 have worked hard to view their hexagonal array as a symmetrical pattern of sticks forming lines within triangles that make up a hexagon. As these groups work out their algebraic solutions to the topic, they are present together in a shared world at an object of interest, which they all see as structured in the same way. In the third case, after much work individually and collaboratively, and incorporating ideas from the ancient tradition of Euclidean geometry, the three students working on the inscribed squares all observe that when square EFGH is dragged within square ABCD the following segments along the outer square change but stay equal in length to each other: AE, CH, DG, BF. They then can all see that they have to construct square MONP within square IJKL so that segments IP, JM, KO, LN stay the same (see Figure 3). They collaborate in a shared world, manipulating a shared object physically, visually and imaginatively within a shared understanding of their problem, the geometric objects, the dynamic dependencies, the representational figure and the software affordances.

Following the phenomenologists, the ethnomethodologists showed that the shared social world is constituted continuously through group interaction (Garfinkel, 1967). In our VMT data, we can study precisely how that is accomplished. We see that it takes place over longer sequences of discourse moves, each centered on elicitation/response adjacency pairs. Carrying out these longer sequences requires maintaining persistent co-attention to a shared object; the being-there-together at the object provides a shared focus for the discourse.
Accompanying this, there must be a shared understanding of the object and of the discourse context so that group members understand each other. If someone does not know what someone else means by a “hexagonal array” or by its “side-length,” does not see the same elements of a symmetrical pattern or the same set of line segments moving together, then the collaborative problem solving cannot continue productively.

Kant (1787/1999) argued that the human mind constitutes meaningful reality through a process of creative discovery, in which structure is imposed to create and discover objects in the world. In the preceding examples, we see how group interaction can constitute the character of objects in the shared world and we have suggested that the shared meaningful world is itself constituted through such interaction. The nature of reality—such as the symmetries of diamond patterns, hexagonal arrays and inscribed squares—is discovered through the creation of interpretive views of objects. Effective perspectives are constrained by reality, which is not knowable except through these views. The creation of perspectives at the level of group cognition shifts the constitutive role from Kant’s individual cognition to group and social cognition. Like the students in the virtual math teams, we first learn to see things as others see them in group-cognitive processes (which generally incorporate culturally sanctioned approaches). Subsequently—due to the power of language (e.g., naming, verbal description)—we can be there with those objects (diamonds, hexagons, squares) when we are not physically (or virtually) present with them in a shared group setting. We can even “internalize” (to use Vygotsky’s metaphor) our ability to be-there-with these meaningful objects in the internal speech of individual thought. However, the fact that introspection of adults discovers (and assumes) the existence of many individual mental objects does not mean that those objects were not at some point in our development internalized from group-cognitive experiences in community contexts. An adequate analysis of cognition should recognize the constitutive roles of group cognition and their integration with phenomena of individual and social cognition.
The research field of CSCL is ethnomethodologically informed, or at least ethnomethodologically influenced. This has not always been the case, although there is a logic to this growing tendency.

Ethnomethodology (EM) is an approach to conducting research in the human sciences founded by Harold Garfinkel (1917-2011) and largely defined by his Studies in Ethnomethodology (Garfinkel 1967; Garfinkel & Rawls 2012). EM addresses the “methods” that people within a given linguistic community use to establish and maintain intersubjective understanding. Since CSCL can be characterized as being focused on joint meaning making, the analysis of prevalent meaning-making methods seems particularly relevant to the methodological quandaries of CSCL research.

Ethnomethodology has been slow to catch on in CSCL, in contrast to its role in allied fields like CSCW, where it seems to be a dominant research paradigm (e.g., see Crabtree 2003). There are a number of theoretical and historical reasons for this. For instance, as discussed below, practitioners of EM eschew research questions and theoretical framings because these could obscure the meaning-making perspective of the people whose interactions are under investigation. This injunction against guiding theory makes it difficult to integrate EM studies into the educational and design agendas of CSCL investigators. In addition, the case-study approach of EM to analyzing naturally occurring events is at odds with the traditional emphasis in educational and psychological research on controlled experiments and statistical generalizations.

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4 Garfinkel died in April 2011. Michael Lynch (2011) wrote an obituary reflecting on his life. His work is outlined in his Wikipedia entry (2012). This issue of *ijCSCL* is dedicated to his vision.

5 Timothy Koschmann (2002a) presented a programmatic description of CSCL in his keynote at CSCL 2002: “CSCL is a field of study centrally concerned with meaning and the practices of meaning making in the context of joint activity, and the ways in which these practices are mediated through designed artifacts.”
On the other hand, there are strong arguments for viewing the ethnomethodological approach as especially appropriate for analyzing computer-supported collaborative learning. In particular, a major stream of research within EM has been conversation analysis. This is the analysis of talk-in-interaction, as pioneered by Harvey Sacks (1965/1995) and other colleagues of Garfinkel. An early finding of conversation analysis was the system of turn taking in face-to-face informal conversation. While this system does not apply directly to such CSCL interactions as online text chat about an academic topic (Zemel & Çakir 2009), the underlying techniques of sequential analysis (systematized in Schegloff 2007) seem highly applicable to the analysis of meaning making in CSCL settings (for an example, see Stahl 2011a). Such sequential analysis explicates the evidence embodied in instances of discourse that reveal meaning-making processes taking place in small groups. It looks at the semantic, syntactic and pragmatic details of how utterances respond to each other and elicit new responses in the flow of group cognition.

The Historical Traditions of CSCL Research

To paint a simplistic picture of the development of CSCL research, let us say that early investigators turned from inspirations in computer science and artificial intelligence to the fields of educational psychology and sociology to find methods of studying the effects of using CSCL systems in classrooms or in laboratories. The theories and research paradigms that they brought in from these established fields focused on either the individual student or the larger society as the unit of analysis. Educational theory operationalizes learning as a hidden change in mental state of student knowledge from before an intervention to after, as measured by pre- and post-tests of individual students. At the other extreme, social science approaches hypothesized societal forces that could not be observed directly, but could be inferred and measured by controlled experiments using statistically significant numbers of randomly selected subjects.

Ethnomethodology—drawing on philosophical influences from phenomenology and reacting against functional approaches to sociology—takes a different tack, centered on what is made visible in the interactions between people. EM argues that one can observe the meaning-making processes at work by carefully studying the discourse between people; one does not have to make inferences about hidden changes in mental models or invisible social structures. Furthermore, EM studies can focus on the small-group unit of analysis, which seems most appropriate to analyzing collaborative learning. While other areas of education and of sociology may seem centrally concerned with individual or societal units of analysis and while collaborative learning may also involve
processes and phenomena at those levels, the meaning making in contexts of joint activity which is definitive of CSCL takes place primarily at the small-group level, even if a complete understanding will need to tie all the levels together (Stahl 2012c).

The ability to conduct microanalysis of interaction was historically made possible by recording technologies. Conversation analysis arose in the age of the tape recorder. That technology made it possible to hear exactly what was said and how it was articulated. It allowed the production of detailed transcripts, which encoded intonation, pauses, emphasis, restarts and overlaps so that the mechanisms of verbal interaction could be studied. Subsequent development of video recording led to analysis of gesture, facial expression, gaze and bodily posture as important but generally unnoticed aspects of interpersonal interaction. For online communication typical of CSCL, computer logs and even the ability to replay synchronous interaction can provide adequate data sources necessary for the study of how students actually engage in computer-supported collaborative learning.

Applied to CSCL, the approach of EM implies that we can observe and report on the ability of given technologies and pedagogies to mediate collaborative interactions between students in concrete case studies. EM suggests ways to do this systematically, with intersubjective validity, and to generalize the findings. Insights from this can be used to critique the designs of interventions and to suggest redesign criteria. To make these claims about EM plausible, we will need to review some of the principles of EM (see also, Stahl 2006a, Chapter 18).

The Theoretical Framing of CSCL Research

As mentioned above, there is a prevailing notion that EM is atheoretical or even anti-theoretical, that it rejects all theorizing. Yet Garfinkel and Sacks (1970) were highly theoretical thinkers, influenced by philosophy, sociology and communication theory. In fact, EM represents a strong theoretical position about the nature of human reality and the possibilities of comprehending it. EM claims that human social behavior is structured by a large catalog of “member methods”—patterned ways of making intersubjective sense with other members of one’s linguistic community. Furthermore, these member methods are “accountable” in the sense that they provide an observable account of their own character. People’s actions are designed so that the meaning of the actions will be recognizable by others within the given discourse situation. This accountability is necessary for intersubjective understanding among members.
But it has the secondary consequence that researchers can understand the methods as well (given certain conditions). The theory of EM thereby explains how EM is possible as a scientific enterprise.

The member methods of a linguistic community contribute significantly to the social order of activities within the community. The social structure is enacted in the very interactions of the members by virtue of their use of these methods; the accountability of the methods, as they are realized, reveals to the other participants (and potentially to researchers) evidences of what is being enacted. As Garfinkel put it, “any social setting [should] be viewed as self-organizing with respect to the intelligible character of its own appearances as either representations of or as evidences-of-a-social-order” (Garfinkel 1967, p. 33). There is reflexivity at work between the meaning of an elemental interaction (e.g., an utterance response pair) and the local context of the on-going discourse, in which the utterances are situated within a context whose significance they interpret in a continuously emergent way. The theory of EM is formulated in its concepts of member methods, accountability, reflexivity, etc.

The reason that EM is often considered atheoretical is that it systematically rejects the kind of theoretical framing that is associated with many other research approaches. For instance, in other paradigms an experiment and its analysis are motivated and structured by a theory or conceptualization of the phenomena to be studied. There may be a specific research question that the researchers have in mind. There may even be hypotheses about how the experiment will turn out based on preconceptions. While scientific researchers must remain open to their hypotheses being disproven by the evidence, the posing of research questions and hypotheses define a research perspective within which the evidence is interpreted. For instance, CSCL discourse data might be coded according to a set of codes designed to make distinctions relevant to this perspective, experimental conditions will be structured to test these distinctions and coders will be trained to categorize their data from this perspective.

EM, in explicit contrast, wants to understand the data from the perspective of the participants in the study (e.g., students). Because the analysis of discourse is a human science, it must take into account what the discourse means for the speakers and audience. The participants are viewed as people engaged in meaning making, and EM researchers want to understand the meaning that the participants are making. EM researchers do not want to impose a perspective on the data analysis that is based on their own preconceived theories about the interaction. Rather, they want to engage in “thick description” (Ryle 1949) of the discourse to explicate the meaning making that is taking place in the discourse and that is displayed in the accountability of how it is formulated. The fact that the discourse is accountably intersubjectively understandable allows the
researcher to analyze the meaning that is implicit in the discourse as it sequentially unfolds.

This is the sense in which EM rejects theory: that it adopts the participant perspective on understanding the meaning in the data, rather than imposing a perspective based on a theoretical research framing. There has been considerable debate within CSCW about how EM analysis can be used to guide design of collaboration systems if it cannot be directed toward theoretical issues (e.g., see Crabtree 2003). But the stricture against theory in EM is only against imposing an a priori analysis framework, not against drawing theoretical consequences from case studies. So one can, for instance, study the discourse of students embedded in a computer-supported interaction, and analyze the nature of the methods they use—which they enact, adapt or create—for achieving their collaborative tasks. The details of these methods can have design implications, such as addressing technical barriers that resulted in unnecessarily cumbersome behaviors. Thus, EM can contribute to the analysis phase of design-based research (DBR Collective 2003), which is a widespread approach in CSCL to the design of effective collaboration technologies.

The Ubiquity of Methods

Ethnomethodology posits the existence of member methods pervading all of social life. EM research for the past fifty years has documented many such methods, for instance in informal conversation, in doctor-patient discussion, in mathematical proof, in criminal interviewing and in workplace communication (Lynch & Sharrock 2003). These methods are often sedimented in the traditional design of the tools we use and in the clichéd turns of speech within our vernacular. They constitute our myriad overlapping cultures.

Sacks (1965/1995) argued that the pervasiveness of member methods meant that one could profitably study almost any interaction and learn from it about the nature of social existence. He argued that the universal application of these methods was necessary if people were to understand each other. In the CSCL literature, one often talks about the establishment and maintenance of “common ground” (Clark & Brennan 1991) as providing the foundation for intersubjective understanding. But, according to EM, it is not a matter of the participants having corresponding mental models of propositional knowledge; rather, intersubjectivity is founded on sharing a world through using shared methods of communication (see also Stahl et al. 2011). These methods provide “resources” for engaging in specific domains of the social world. According to the EM viewpoint, collaborative learning does not consist in the storing of
propositional knowledge as mental contents in individual minds, but in the increasing ability to enact relevant resources or shared practices in interactions with others.

By looking carefully at interactions in CSCL settings, we can analyze the methods being applied. Because the acceptance of these methods is widespread within a culture, the results of a single case study can have quite general ramifications. Of course, to accept the implications of a single case study—or even a small catalog of case studies analyzing variations on a method—as valid and of general applicability, we need to ensure lack of bias or idiosyncrasy. This is usually addressed in EM by “data sessions” and other mechanisms to involve multiple analysts (Jordan & Henderson 1995). If discourse under analysis displays an account of itself, then a group of experienced analysts who share the relevant cultural understanding with the discourse participants should be able to reach a consensus about the meaning being created in the discourse. EM case-study publications frequently include very detailed transcripts of the relevant discourse excerpts to enable readers to confirm the analysis based on their own cultural understanding. Because meaning and meaning-making methods are always situated in unique, evolving, emergent contexts, the case study is the preferred genre of presentation for EM studies of CSCL.
Cognizing mediating: Unpacking the Entanglement of Artifacts with Collective Minds

The age of simple objects like well-designed artifacts, minds confined inside of skulls, and cultures cloistered in the tacit background has been left in the fading past according to current socio-cultural theory. We are now enmeshed in dialectical processes of social enactment, whereby designed objects continue to evolve well after they enter into the structuring of our thought patterns.

Biological human evolution has long since transformed itself into cultural evolution, proceeding at an exponential pace. Along the way, thought overcame the limits of individual minds to expand with the power of discourses, inscriptions, digital memories, computational devices, technological infrastructures, computer-supported group cognition, and virtual communities. Both human cognition and its mediation by technological artifacts morph from fixed nouns into process verbs, like “cognizing mediating”—where human cognition and technological media shape each other in ways we are just beginning to conceptualize.

The owl of Minerva flies only at night, according to Hegel’s (1807/1967) metaphor: theory—which is one’s time grasped in concepts—lags behind the continuous unfolding of practice. As today’s viral software successes rapidly outstrip our design theories, we must try to understand the ways in which new generations of users adopt and adapt their digital tools, thereby defining and redefining their conceptual, social, and pragmatic ties to their worlds. Hegel theorized the dialectic between subject and object, proposing that the identity of the human subject is formed when a subject subjects an object to goal-oriented design (Stahl 2006a, p. 333f), creating an artifact within the effort to forge intersubjectivity and its spin-off, the individual’s self.

Vygotsky (1930/1978) recognized the role of double stimulation in mediated cognizing: that the subject’s access to an object is mediated by tools
such as hammers, names, and physical-symbolic inscriptions, so that in higher-order human cognizing we are stimulated by both an intentional object and a cognizing-mediating tool. It is this mediation of cognition by artifacts and via other people that opens the zone of proximal development, allowing the individual mind to first exceed and then later extend its limits. Engeström’s (1987) concept of expansive learning added the cultural dimensions from Marx’ social theory to Vygotsky’s simple triangle of subject-artifact-object. Henceforth, socio-technical understandings of artifacts have to situate them culturally, historically, politically.

We have considered the labyrinthine nature of the artifact’s affordances previously within theories of human-computer interaction (Hutchins 1999; Norman 1991), cognitive science (Gibson 1979; Hutchins 1996) and CSCL (Bonderup Dohn 2009; Dwyer & Suthers 2006; Jones, Direkinck-Holmfeld & Lindstrom 2006; Suthers 2006; van der Pol, Admiraal & Simons 2006). In particular, based on Merleau-Ponty’s (1945/2002) philosophy, Bonderup Dohn argued that the affordances of an artifact were potentials realized in response to human behaviors.

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In this issue’s opening essay, Maarten Overdijk, Wouter van Diggelen, Paul A. Kirschner & Michael Baker explore the nature of artifacts by comparing the theory of affordances with the theories of structuration and of instrumental genesis. Structuration (Giddens 1984a; Orlikowski 2008) is a well known theory developed to account for the dialectic between social structures and the local interactions which are both constrained by these structures and reproduce them. Instrumental genesis is a recent theory developed in France by Pierre Rabardel and his colleagues. This issue of *ijCSCL* introduces the theory of instrumental genesis to the CSCL community and explores how the theory might impact work in CSCL, at methodological, technological, and theoretical levels.

Our first article compares the three major recent theories about the interaction between artifacts and people, using a concrete case study of a typical CSCL setting. It argues in favor of the general approach of instrumental genesis as an analysis of the micro-genesis of artifacts and as the best available description of the nature of tools, particularly for CSCL. The theory of affordances tends to focus on the individual, for instance with Gibson’s biological perspective or Norman’s use of mental models, or Piaget’s schemas in individual minds. In contrast, the sociological theory of structuration focuses on the societal or cultural level. The theory of instrumental genesis can more naturally be applied to the small-group collective level central to CSCL, as the first article does in discussing how triads of students enacted a feature of an argumentation-support software system.
The paper presents a “theoretically grounded” conception of the artifact-agent connection. A next step would be to explore an empirically grounded analysis of the connection. While the article referred to data from a CSCL experiment, it simply used high-level descriptions of the data to illustrate aspects of the theories being described. It will be important in the future to analyze such data in detail to see if the connections of groups of students to computer-support systems follow the contours of one or more of the three theories, or whether they display different lines of development. Furthermore, it will be useful to consider more complex technologies, whole meso-level infrastructures (Jones, Dirckinck-Holmfeld & Lindstrom, 2006) rather than isolated functions. For instance, in an online course, small groups may have to negotiate the coordinated use of hundreds of functions in Blackboard, Google search, Wikipedia, Facebook, Google Docs, iChat, Gmail, Word, and PowerPoint in order to produce a one-week assignment. Such an undertaking invokes the use of individual experience or expertise, established social practices in the school culture, consideration of course requirements and project goals, as well as collaborative discourse and trials by the small groups. The resultant computer-supported effort assembles and interprets a complex technical infrastructure, increases the expertise of the group participants, and provides a medium for group knowledge building. The connection of the collaborative group with the technical infrastructure continuously evolves through use during a term.

* * *

Having glimpsed the potential relevance of the theory of instrumental genesis to CSCL, we turn next to a discussion of that theory within the context of CSCL system design. Jacques Lonchamp returns to these pages after having presented his analyses of CSCL design options (Lonchamp 2006; 2009). He now argues for applying Rabardel’s theory by expanding Engeström’s (1987) Activity Theory triangle of mediations, to explicitly represent both the processes of mutual shaping of agent and artifact and the specific role of the teacher in CSCL classrooms: He pictures the various mediated interconnections among tool, designer, teacher, student, peer, and tutor. Furthermore, he discusses how the agent-artifact connection—embodied in Rabardel’s conception of the instrument—evolves over time through usage and re-design.

The paper concludes with a review of CSCL system design approaches to supporting “instrumentalization” by teachers and students. Although it comes close to describing design-based research (Brown 1992; DBR Collective 2003), this review does not name it. Design-based research is a dominant approach within CSCL research to integrating system design, usage analysis, educational research, and practical classroom interventions. It was developed in response to the need to conduct user-centered design of innovative educational software for collaborative groups—a realm lacking in detailed theories, specific analysis
methods, adequate software, or design guidelines. Perhaps an explicit combination of Rabardel’s theory with data from design-based research projects could provide empirically grounded insights into the mutual shaping of CSCL software and group cognition in on-going design and usage processes.

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The third paper, by Giuseppe Ritella & Kai Hakkarainen, situates Rabardel’s theory within the context of knowledge-building practices, as these are conceptualized in recent work at the Scandinavian-led Knowledge Practices Laboratory (KP-Lab). This context is populated with social practices grounded in knowledge-building artifacts (Hakkarainen 2009) and structured in space and time by chronotypes (Ligorio & Ritella 2010). The knowledge-building artifacts are instruments in Rabardel’s sense; they provide for advanced forms of Vygotskian double stimulation (Lund & Rasmussen 2008). The whole context is the result of the cultural evolution (Donald 1991; 2001) that led up to our involvement with digital information and communication technologies in an increasingly powerful, distributed, and mediated cognitive universe.

From prehistoric times to the present, the proliferation of forms of inscription (Latour 1990) transformed the human cognitive architecture as profoundly as earlier leaps in biological evolution, allowing radical externalization and collectivization of cognition. In a sense, CSCL aims to push this further, designing collaboration media to foster group cognition that can lead to new forms of individual learning, team knowledge building, and community social practices. To the extent that this is true, we need to design new tasks for computer-supported teams, aiming for cognitive achievements beyond the reach of individual team members without computer supports. The goal of CSCL research should not be to simply demonstrate repeatedly that individuals learn better in online groups, but to design and investigate tasks that go beyond traditional instruction. Recent findings concerning “productive failure” (Kapur & Kinzer 2009; Pathak et al. 2011) illustrate how groups with challenging tasks may be learning in ways that defy standard testing indicators, but that contribute to increased problem-solving skills of the groups and ultimately of their members.

The analysis of instrumental genesis within the framework of knowledge building points to both the potentials of CSCL and the barriers to widespread dissemination. The historical evolution of tools as “epistemic artifacts” can itself be seen as a knowledge-building accomplishment of the greatest cognitive consequence, related to Vygotsky’s—perhaps misleadingly named—notion of “internalization” by individuals of skills germinated in intersubjective circumstances. On the other hand, the complexity involved in successful instrumental genesis translates into severe barriers when, for instance, one tries to promote adoption of CSCL technologies, pedagogies, chronotypes, and
educational philosophies in established school communities and institutions. Parallel to the difficulties of the students struggling to enact the technological affordances are the difficulties of the researchers, trying to document, analyze, and conceptualize the tortuous paths of instrumental genesis in CSCL.

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This issue of *ijCSCL* balances its featured discussion of CSCL theory with important presentations of CSCL pedagogy, CSCL technology, and CSCL analysis. The paper by Carmen G. Zahn, Karsten Krauskopf, Friedrich W. Hesse & Roy Pea investigates the provision of pedagogical guidance oriented to social interaction versus that oriented to cognitive tasks. An experiment with groups of 16-year-old students using video tools for history lessons indicates that support for their collaborative interactions was more effective than guidance directly related to their assigned tasks. This demonstrates the centrality of issues of adopting and exercising interaction practices in collaborative learning, and has implications for scripting group tasks, orchestrating group work, and guiding group collaboration.

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Imagine trying to analyze a large corpus of online collaborative discussion to see how often groups under different conditions articulated specific components of scientific argumentation, such as claims, evidence, critique, etc. The contribution by Jin Mu, Karsten Stegmann, Elijah Mayfield, Carolyn Rosé & Frank Fischer describes a promising approach to automating such analysis utilizing current and innovative techniques of natural-language processing. The first step—not previously fully automated—is to segment the corpus into utterances (whether phrases, clauses, sentences, or paragraphs) that each expresses a specific component of argumentation. Until this can be automatically accomplished reliably and with generality, the dream of automating the coding of micro-argumentation will remain out of reach. To overcome typical over-generalization to specific training sets, the approach tested here replaces the context-specific terms in a corpus with syntactic descriptors and replaces the nouns with entity categories—e.g., substituting “location” or “city” for “Sydney.” This pre-processing allows the software analysis to compute rules that are less context dependent.

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Collaborative learning can be much more complex to support and to analyze than individual learning. For instance, computer-based cognitive tutors have been effective in supporting individual learning of traditional school mathematics for years and are used widely in classrooms, but they have rarely been applied successfully to collaborative learning. In the empirical study reported here by Nikol Rummel, Dejana Mullins & Hans Spada, algebra tutoring
technology is combined with scripting to explore potential benefits for small-group learning. As described by the theory of instrumental genesis, the use of new technologies by student groups must be enacted by the students. This means that a comparison of conditions with and without computer supports involves significant differences in the tasks faced by the students, including learning to use the tools and negotiating how to take advantage of them. Different enactments by different teams can obscure statistical measures of learning that average across the cases. As seen in this study, narrative analysis of specific cases can provide incisive insight into how the technologies are being used and how they are actually affecting the group knowledge-building processes. Rigorous research into the effectiveness of CSCL tools can require multiple coordinated methods, responsive to the complexities of the collaborative-learning issues involved, as discussed in this article.
Supporting Group Cognition in an Online Math Community: A Cognitive Tool for Small-group Referencing in Text Chat

Abstract. The Virtual Math Teams Project is exploring how to create, structure, support and assess an online chat-based collaborative community devoted to mathematics discourse. It is analyzing the forms of group cognition that emerge from the use of shared cognitive tools with specific functionalities. Centered on a case study of a synchronous online interchange, this essay discusses the use of a graphical referencing tool in coordination with text chat to achieve a group orientation to a particular mathematical object in a shared whiteboard. Deictic referencing is seen to be a critical foundation of intersubjective cognitive processes that index objects of shared attention. The case study suggests that cognitive tools to support group referencing can be important to supporting group alignment, intentionality and cognition in online communities such as this one for collaborative mathematics.

Suppose one wanted to establish a collaborative community with a certain focus, say to explore mathematics (e.g., the kind of math taught in school or accessible to interested students). How might one go about doing this? How would one invite people, where would they congregate, how would they communicate, what kinds of social practices would emerge, who would provide leadership, whence would knowledge appear? The obvious approach today is to build an online community of people who want to discuss math. Research in computer-supported collaborative learning and working (CSCL and CSCW) has taught us that this requires a well-integrated infrastructure, not just a simple cognitive tool or a generic communication medium. For instance, the following range of issues would have to be addressed: how should the software environment be designed; what kind of curriculum or domain content should be
included; how are working groups to be formed; how will participants be recruited? The design of cognitive tools to support such an online collaborative community would involve many inter-related considerations, most of which are not yet well understood.

Cognitive tools for collaborative communities are essentially different from cognitive tools for individuals. A number of forthcoming publications detail the following considerations (Dillenbourg & Traum 2006; Jones, Dirckinck-Holmfeld & Lindström 2006; Stahl 2006a):

1. The use of cognitive tools by a collaborative community takes place through many-to-many interactions among people, not by individuals acting on their own.

2. The cognition that the tools foster is inseparable from the collaboration that they support.

3. The relevant cognition is the “group cognition” that is shared at the small-group unit of analysis; this is a linguistic phenomenon that takes place in discourse, rather than a psychological phenomenon that takes place in an individual’s mind.

4. The tools may be more like communication media than like a hand calculator—they do not simply amplify individual cognitive abilities, they make possible specific forms of group interaction.

5. Rather than being relatively simple physical artifacts, tools for communities may be complex infrastructures.

6. Infrastructures do not have simple, fixed affordances designed by their creators; they are fluid systems that provide opportunities that must be specified by users and enacted by them.

7. The community must interpret the meanings designed into the tools, learn how to use the tools, share this understanding and form social practices or methods of use.

8. Analyzing the effectiveness of these tools requires a special methodology that can analyze the methods developed by the community for taking advantage of the infrastructure to accomplish its collaborative activities.

9. The community with its tools forms a complex system that cannot be modeled through simple causal relationships, because the whole is both over-determined and open-ended; the community is made possible by its infrastructure, but also interprets the meaning of its tools and adapts their affordances.
This essay tries to respond to these considerations without having the space to present them in depth. It reports on a current effort to develop a cognitive tool for an online community of mathematics discourse. Experience—along with the preceding considerations—has shown that the design of software tools for collaborative learning must consider above all else how people will actually use the tool. Therefore, our design effort was structured as a design-based research experiment, in which a relatively simple solution is first tried out in a realistic small-scale setting. The results of actual usage are analyzed to assess what worked and what barriers were encountered. Successive re-design cycles attempt to overcome the barriers that users encountered and to evolve a tool and approach that provide increasingly effective support for a gradually emergent online community. This user-centered approach—applied to a growing community of users rather than to subjects representing an imagined “typical” individual user—focuses on the details of how the community interacts through the tool.

More specifically, we will look at a cognitive tool that was recently added to the infrastructural support for this community. The tool allows users to relate work in a text chat stream with work done in a shared whiteboard drawing area. The tool draws lines from a chat message to other chat messages and/or to areas in the whiteboard. We call this tool a “graphical referencing tool” because it supports the ability of a message to reference an item already existing in the online environment by drawing a line from the message to the item.

After briefly describing our research project and discussing our methodology for analyzing usage, we will present a case study of how students used the cognitive tool for referencing. Close analysis of a brief excerpt from an actual student interaction using the tool will illustrate both how complex the achievement of shared references can be and how crucial referencing can be for the group cognition that takes place. Findings of the case study will then motivate consideration of conceptual issues in understanding referencing: reflections on the epistemology and pedagogy of referencing will provide insight into issues of gesture, common ground, boundary objects and intentionality in group cognition.

An Experiment in Designing an Online Chat Community

The Virtual Math Teams (VMT) project at the Math Forum (http://mathforum.org/vmt) is a research project now underway to explore some of the issues posed above. In order to understand the experience of people
and groups collaborating online in the VMT service, the researchers in the project look in detail at the interactions as captured in computer logs. In particular, the project is studying groups of three to six middle- or high-school students discussing mathematics in chat rooms. The logs that are collected capture what the participants see to a good approximation.

The VMT project was designed to foster, capture and analyze instances of “group cognition” (Stahl 2006a). The project is set up so that every aspect of the communication can be automatically captured when student groups are active in the online community, so that the researchers have access to virtually everything that enters into the communication and is shared by the participants. All interaction takes place online, so that it is unnecessary to videotape and transcribe. Each message is logged with the name of the user submitting it and the time of its submission. Similarly, each item placed in the shared whiteboard is tagged with the name of its creator and its creation or modification time. The chat is persistent and the history of the whiteboard can also be scrolled by participants, and later by researchers.

Although many things happen “behind the scenes” during chat sessions—such as the production of the messages, including possible repairs and retractions of message text before a message is sent, or things that the participants do but do not mention in the chat—the researcher sees almost everything that the participants share and all see. While the behavior of a participant may be influenced on an individual basis—such as by interactions with people outside of the chat or by the effects of various social and cultural influences—the researchers can generally infer and understand these influences to the same extent as the other participants (who typically do not know each other outside of the chats). These “external” factors (including the participants’ age, gender, ethnicity, culture) only play a role in the group interaction to the extent that they are somehow brought into the discourse or “made relevant” in the chat. In cases where they play a role in the group, then, they are also available to the researchers.

In particular, the sequentiality of the chat messages and of the actions in the whiteboard is maintained so that researchers can analyze the phenomena that take place at the group level. The other way in which the group interaction may be influenced from outside of activities recorded in the chat room is through general background knowledge shared by the participants, such as classroom culture, pop culture or linguistic practices. If the participants meet on the Internet and do not all come from the same school and do not share any history from outside of the VMT chats, then researchers are likely to share with the participants most of the background understanding that the participants themselves share.
This is not to say that the researchers have the same experience as the participants, but their resources for understanding the chat are quite similar to the resources that the participants had for understanding and creating the chat despite the dramatic differences between the participant and researcher perspectives. Participants experience the chat in real time as it unfolds on their screen. They are oriented toward formulating their messages to introduce into the chat with effective timing. Researchers are engaged in analyzing and recreating what happened, rather than participating directly in it. They are oriented toward understanding why the messages were introduced when and how they were.

We want to understand how groups construct their shared experience of collaborating online. While answers to many questions in human-computer interaction have been formulated largely in terms of individual psychology, questions of collaborative experience require consideration of the group as the unit of analysis. Naturally, groups include individuals as contributors and interpreters of content, but the group interactions have structures and elements of their own that call for different analytic approaches. In particular, the solving of math problems in the chat environment gets accomplished collaboratively, interactionally. That is, the cognitive work is done by the group.

We call this accomplishment group cognition—a form of distributed cognition that may involve advanced levels of cognition like mathematical problem solving and that is visible in the group discourse, where it takes place. It is possible to conduct informative analyses of chats at the group unit of analysis, without asking about the individuals—e.g., their motivations, internal reflections, unexpressed feelings, intelligence, skills, etc.—beyond their participation in the group interaction. Of course, there are also fascinating questions about the interplay between group cognition and individual cognition, but we will not be considering those in this essay.

The VMT project is studying how small groups of students do mathematics collaboratively in online chat environments. We are particularly interested in the new methods that the chat members must develop to conduct their interactions in an environment that presents new affordances for interaction. “Member methods” (Garfinkel 1967) are interactional patterns that participants in a community adopt to structure and give meaning to their activities. A paradigmatic example of member methods is the set of conventions used by speakers in face-to-face conversation to take turns talking (Sacks, Schegloff & Jefferson 1974). The use of such methods is generally taken-for-granted by the community and provides the social order, meaning and accountability of their activities. Taken together, these member methods define a group culture, a shared set of ways for people interacting to make sense together of their common world. The methods adopted by VMT participants are subtly
responsive to the chat medium, the pedagogical setting, the social atmosphere and the intellectual resources that are available to them. These methods help define the nature of the collaborative experience for the small groups that develop and adopt them. Through the use of these methods, the groups construct their collaborative experience. The chat takes on a flow of interrelated ideas for the group, analogous to an individual’s stream of consciousness. The referential structure of this flow provides a basis for the group’s experience of intersubjectivity and of a shared world.

As designers of educational chat environments, we are particularly interested in how small groups of students construct their interactions in chat media that have different technical features. How do the students learn about the meanings that designers embedded in the environment and how do they negotiate the methods that they adopt to turn technological possibilities into practical means for mediating their interactions? Ultimately, how can we design with students the technologies, pedagogies and communities that will result in desirable collaborative experiences for them? Our response to the question of how cognitive tools mediate collaborative communities is to point to the methods that interactive small groups within the community spontaneously co-construct to carry out their activities using the tools.

To explore this complex topic within the confines of this essay, we will look at a brief excerpt of one dyad of students within an online small group using the affordances of the technological environment of the VMT project at one point in its development. Specifically, we look at how the students reference a particular math object in the virtual environment. We will see a number of methods being used within a 16-line excerpt. We will also mention other methods that we have observed students employing for referencing in similar chat sessions.

Technology for Referencing in a Chat Environment

In our design-based research at the Virtual Math Teams project (Stahl 2005a), we started by conducting chats in a variety of commercially available environments, including AOL Instant Messenger, Babylon, WebCT, Blackboard. Based on these early investigations, we concluded that we needed to include a shared whiteboard for drawing geometric figures and for persistently displaying notes. We also found a need to minimize “chat confusion” by supporting explicit referencing of response threads (Cakir, Xhafa, Zhou & Stahl 2005; Fuks, Pimentel & de Lucena 2006). We decided to adopt and adapt ConcertChat, a
research chat environment with special referencing tools (Mühlpfordt & Wessner 2005). By collaborating with the software developers, our educational researchers have been able to successively try out versions of the environment with groups of students and to gradually modify the environment in response to what we find by analyzing the chat logs.

Figure 1. Screen view of ConcertChat with referencing. The image has been modified to show graphical references from chat lines 1, 5, 10 and 12 to the whiteboard. The drawing from the whiteboard has been duplicated in the margin twice to accommodate this. Only the reference from a single selected chat line would actually appear at any given time.

The ConcertChat environment allows for a variety of referencing methods in math chats:

- **Referencing the whiteboard from a posting.** When someone types a new chat message, they can select and point to a rectangular area in the whiteboard. When that message appears in the chat as the last posting or as a selected posting, a bold line appears connecting the text to the area of the drawing (see Figure 1).

- **Referencing between postings.** A chat message can point to one or more earlier textual postings with a bold connecting line, like whiteboard references. ConcertChat includes a threaded view of the chat postings that, based on the explicit references between postings, displays them like a typical
threaded discussion with responses indented under the posting that they reference.

- **Referencing a recent drawing.** The shared whiteboard allows chat participants to create drawings. As new objects are added to the drawing by participants, an implicit form of referencing occurs. Participants typically refer with a deictic term in their textual chat to a new addition to the drawing, whose recent appearance for the group makes it salient.

- **Linguistic referencing.** Of course, one can also make all the usual verbal references to an object on the whiteboard or posting in the chat stream: using deictic terms (*that, it, his, then*); quoting part of an earlier posting; or citing the author of a previous posting.

In May 2005, we conducted a series of chats using ConcertChat. We formed five virtual math teams, each containing about four middle-school students selected by volunteer teachers at different schools across the USA. The teams engaged in online math discussions for four hour-long sessions over a two-week period. They were given a brief description of a non-traditional geometry environment: a grid-world where one could only move along the lines of a grid (Krause 1986). The students were encouraged to come up with their own questions about the grid-world, such as questions about shortest paths between points A and B in this world.

The chats were facilitated by a member of our research project team. The facilitator welcomed students to the chat, pointed them toward the task, briefly demonstrated the graphical referencing tool and then kept generally quiet until it was time to end the session. We then analyzed the resultant chat logs in order to draw design implications for revising the tools and the service.

### An Analysis of a Case of Referencing

The chat log excerpt visible in Figure 1 is reproduced in Figure 2 (with line numbers added to enable referencing in this essay). In this interactional sequence, two students discuss parts of a drawing that has already been constructed in the shared whiteboard by the larger group to which they belong. The group had created the drawing as part of discussions about shortest paths between points A and B in a grid-world. In particular, a red triangle, ABD, was drawn with sides of length 4, 6 and $2\sqrt{13}$. A thick black staircase line was drawn as a path on the grid from A to B. In this excerpt, the students propose a math problem involving this drawing.
The message in line 1 of the chat excerpt (see Figure 2) makes a bid at proposing a mathematical question for the group to consider: “What is the area of this shape?” This is accompanied by a graphical reference to the whiteboard. The reference does not indicate a specific area—apparently ImH did not completely succeed in properly using this new referencing tool. Line 2 raises the question, “Which shape?” pointing out the incompleteness of the previous message’s reference. The proposal bid in line 1 calls for a proposal response, such as an attempt to answer the question. However, the question was incompletely formed because its reference was unclear, so it received a call for clarification as its immediate response. Lines 3 and 4 display a recognition and agreement of the incomplete and problematic character of the referencing.

Lines 5 and 6 offer a repair of line 1’s problem. First, line 5 roughs in the area that may have been intended by the incomplete reference. It includes a complete graphical reference that points to a rectangular area that includes most of the upper area of rectangle ACBD in the drawing. The graphical referencing tool only allows the selection of rectangular areas, so line 5 cannot precisely specify a more complicated shape. The text in line 5 (“kinda like this one?”) not only acknowledges the approximate nature of its own referencing, but also acknowledges that it may not be a proper repair of line 1 and accordingly
requests confirmation from the author of line 1. At the same time, the *like* reflects that this act of referencing is providing a model of what line 1 could have done. Peer instruction in the use of the software is taking place among the students as they share their growing understanding of the new chat environment.

Line 5 is accompanied by line 6, which provides a textual reference or specification for the same area that line 5 pointed to: the one highlighted in black (the staircase line) and dark red (lines AC and CB). The inexact nature of the graphical reference required that it be supplemented by this more precise textual reference. Note how the sequence of indexical attempts in lines 1, 2, 5 and 6 successively focuses shared attention on a more and more well-defined geometric object. This is an interactive achievement of the group. The reference was not a simple act of an individual. Rather, it was accomplished through an extended interaction between ImH and Jas, observed by others and situated among the math objects constructed by the whole group of students in the chat room.

Lines 5 and 6 were presented as questions calling for confirmation by ImH. Clarification follows in line 7 from ImH: “between the stairs and the hypotenuse.” Line 8’s “Oh” signals mutual understanding of the evolving reference and the establishment of an agreed upon boundary object (Star 1989) for carrying on the mathematical investigation incompletely proposed in line 1. Now that the act of referencing has been successfully completed by the group, the group can use the referenced area as a mathematical object whose definition or meaning is intersubjectively understood. Viewed at the individual unit of analysis, the referenced area can serve as a boundary object shared among the interpretive perspectives of the interacting individuals. In other words, it becomes part of the common ground (Clark & Brennan 1991) shared by the students. The referencing interaction established or grounded this. Note, however, that what took place was not an aligning of pre-existing individual opinions—as the theory of common ground is often taken to imply—but a group process of co-constructing a shared reference through a complex interaction involving many resources and social moves.

Now that a complete reference has been constructed to a math object that is well enough specified for the practical purposes of carrying on the chat, Jas launches into the problem solving by raising an issue that must first be dealt with. Line 9 says that calculating the area now under consideration is tricky. The tricky part is that the area includes certain little “sectors” whose shapes and areas are non-standard. Line 9 textually references “each little ‘sector’.” *Little* refers to sub-parts of the target area. *Each* indicates that there are several such sub-parts and *sector*, put in scare quotes, is proposed as a name/description of these hard-to-refer-to sub-parts.
Clarification of the reference to sectors is continued by lines 10 and 12. These lines compare two sectors, demonstrating that they are different by showing that one is smaller than the other. Lines 10 and 12 reference two different sectors, both with the same textual, deictic description: *this section*. It is possible to use the identical description twice here because the text is accompanied by graphical references that distinguish the two sectors. Line 10 points to the small grid square inside of rectangle ACBD in the upper left-hand corner adjacent to point A. Line 12 points to the next grid down the hypotenuse (see Figure 1). Because of the roughness of the graphical reference tool, lines 10 and 12 can only indicate the squares of the grid, not the precise odd-shaped sectors that are of concern in the group discourse. On the other hand, the textual clause, *this section* has been given the meaning of the odd-shaped sub-areas of the area “between the stairs and the hypotenuse,” although it cannot differentiate easily among the different sections. The carefully constructed combination of graphical and textual referencing accomplished in lines 10 and 12 was needed to reference the precise geometric objects. The combination of the two textual lines, with their two contrasting graphical references, joined into one split sentence was necessary to contrast the two sectors and to make visible the tricky circumstance. In this way, the discourse succeeded in constituting the complicated geometric sectors despite the limitations of the tool on its own and of textual description by itself.

Line 13 responds to the tricky issue by treating it as a non-essential consequence of inaccurate drawing. By proposing that the group “assume those lines are on the blocks,” this posting treats the difference among the sectors as due to the inaccuracy of the drawing of the thick black staircase line in not precisely following the grid lines. Physical drawings are necessarily rough approximations to idealized mathematical objects in geometry. Lines drawn with a mouse on a computer screen tend to be particularly rough representations. The implication of line 13 is that the tricky issue is due to the inaccurate appearance of the lines, but that the faults of the physical drawing do not carry mathematical weight and can be stipulated away. However, line 14 questions this move. It first makes sure that line 13’s reference to *those lines* was a reference to the staircase lines that form part of the perimeter of the target area and of its different-sized sectors. When line 15 confirms that line 13 indeed referenced the staircase lines, line 16 responds that “they already are on the blocks”—in other words, the tricky situation was not due to inaccuracies in the drawing but the staircase lines were indeed already *taken as* following the grid for all practical purposes. The problem was still seen to be a tricky one once the mathematical object was clearly referenced and specified.

We see here that referencing can be a complex process in online mathematical discourse. In a face-to-face setting, the participants could have pointed to details of the drawing, could have gesturally described shapes, could
have traced outlines or shaded in areas either graphically or through gestures with ease. Conversationally, they could have interrupted each other to reach faster mutual orientation and understanding. Online, the interaction is more tightly constrained and burdensome due to the restricted nature of the affordances of the software environment. On the other hand, we have seen that middle-school students who are new to the graphical tools of ConcertChat, as well as to online collaborative mathematics, can call upon familiar resources of textual language, drawing, pointing and school mathematics to construct interaction methods that are seen to be amazingly sophisticated, efficient, creative and effective when analyzed in some detail.

Methods of Making Referential Sense

We have here only been able to look at what took place in a single effort to reference a mathematical object. In the series of chats that this effort was taken from, we observed groups of students engaging in a variety of other referencing methods within this version of ConcertChat. (For additional uses of the referencing tool, see Mühlpfordt & Wessner 2005). Common methods in our chats included the following:

• Graphical references to previous messages were sometimes used to make salient a message from relatively far back in the chat. Without the graphical referencing functionality, this would have required a lengthy textual explanation justifying change of topic and quoting or describing the previous message.

• Some students used graphical references to previous messages to specify a recipient for their new posting. If a student wanted to address a question to a particular student rather than to the group as a whole, he or she would accompany the question with a graphical reference to a recent posting by that student. (This was a use of graphical referencing not at all anticipated by the software tool designers or VMT researchers.)

• It is common in chat for someone to spread a single contribution over two or more postings (e.g., lines 10 and 12). In conversation, people often retain their turn at talk by indicating that they are not finished in various ways, such as saying “ummm.” In generic chat systems, people often end the first part of their contribution with an ellipsis (…) to indicate that they will continue in a next posting. In ConcertChat, students sometimes graphically referenced their first posting while typing their second. Then the two parts
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would still be tied together even if someone else’s posting (like line 11) appeared in the meantime.

• Similarly, students graphically referenced their own previous posting when repairing a mistake made in it. The reference indicates that the new posting is to replace the flawed one.

• In chat, where the flow of topics is not as constrained as in conversation, it is possible for multiple threads of discussion to be interwoven. For instance, line 11 starts to discuss perimeter while area is still being discussed. Graphical references are used to tie together contributions to the same thread. For instance, line 12 might have referenced line 10 graphically.

• The graphical referencing tool is treated as one of many available referencing resources. Deictic terms are frequently used—sometimes in conjunction with graphical referencing (e.g., line 5).

• In textual chat, as in spoken conversation, sequential proximity is a primary connection. By default, a posting is a response to the immediately preceding post. Chat confusion arises because sequentiality is unpredictable in chat; people generally respond to the most recent posting that they see when they start to type, but by the time their response is posted other postings may intervene. Interestingly, the recency of drawings may function as a similar default reference. Students frequently refer to a line that was just added to the whiteboard as that line without needing to create a graphical reference to it.

• Of course, purely textual references are also widely used to point to postings, people, groups, drawings, abstractions and math objects.

The many forms of referencing in chat tie together the verbal and graphical contributions of individual participants into a tightly woven network of shared meaning. Each posting is connected in multiple ways—explicit and implicit—to the flow of the shared chat (Stahl 2005a). The connections are highly directional, granting a strong temporality to the chat experience (hard to fully appreciate from a static log).

The being-there-together in a chat is temporally structured as a world of future possible activities with shared meaningful objects. The possibilities for collaborative action are made available by the social, pedagogical and technical context (world, situation, activity structure, network of relevant significance) (Heidegger 1927/1996, §18). While the shared context is opened up, enacted and made salient by the group in its chat, aspects of the discourse context appear as designed, established or institutionalized in advance. They confront the
participants as a world filled with meanings, priorities, resources and possibilities for action. It is a world whose features, meanings and co-inhabitants are initially largely unknown.

We are interested in providing cognitive tools to help groups of students navigate worlds of online collaborative mathematical discourse. We want to support their efforts to build collaborative knowledge. Since the Greeks and especially following Descartes, the issue of how people can know has been called “epistemology.” We have seen in our case study that methods of referencing can play an important role in grounding the construction of shared knowledge in an environment like VMT. Conceptually, referencing can be seen as a key to the question of how groups can construct collaborative knowledge.

Epistemology of Referencing

Referencing is a primary means for humans to establish joint attention and to make shared meaning within a (physical or virtual) world in which they find themselves together. Vygotsky, in a particularly rich passage, described the interactional origin of pointing as an example of how gestures become meaningful artifacts for individual minds through social interaction:

A good example of this process may be found in the development of pointing. Initially [e.g., for an infant], this gesture is nothing more than an unsuccessful attempt to grasp something, a movement aimed at a certain object which designates forthcoming activity…. When the mother comes to the child’s aid and realizes this movement indicates something, the situation changes fundamentally. Pointing becomes a gesture for others. The child’s unsuccessful attempt engenders a reaction not from the object he seeks but from another person. Consequently, the primary meaning of that unsuccessful grasping movement is established by others…. The grasping movement changes to the act of pointing. As a result of this change, the movement itself is then physically simplified, and what results is the form of pointing that we may call a true gesture. (Vygotsky 1930/1978, p. 56, italics added)

The pointing gesture is perhaps the most fundamental form of deictic referencing. In its origin where the infant begins to be socialized into a shared world, the meaning of the gesture emerges interactionally as the participants orient to the same object and recognize that they are doing so jointly. This fundamental act of collaborative existence simultaneously comes to be symbolized for them by the pointing gesture, which is practiced, repeated and abstracted by them together over time and thereby established as meaningful.
The mother and infant become an organic small group, caring for shared objects by being-in-the-world-together and understanding as collaborative practice the symbolic meaning of the physical gesture as a referencing artifact.

In grasping, the infant’s being-in-the-world is intentionally directed at the object; the existence of the pointing infant is a being-at-the-object (Husserl 1929/1960). When the mother joins the infant by transforming his individual grasp into a joint engagement with the object, the intentionality of the infant’s grasp becomes intersubjective intentionality, constituting the infant and mother as being-there-together-at-the-object (Heidegger 1927/1996, §26). For Husserl, consciousness is always consciousness-of-something. Human consciousness is intentional in the sense that the conscious subject intends an object, so that the subject as consciousness is at the object. Heidegger transformed this idealist conception into an embedded analysis of human being-there as being involved in the world. Heidegger’s analysis builds up to the brink of a foundational social philosophy of being-there-together, but then retreats to an individualistic concern with the authentic self (Nancy 2000; Stahl 1975). Vygotsky points the way to a fully social foundation, interpreting Marx’ social praxis in social-psychological terms, such as in the intersubjective interaction of the infant-mother bonding.

Epistemology as a philosophic matter is a consequence of the Platonic and Cartesian separation of mind and meaning from the physical existence of objects in the world. The “problem of epistemology” is the question of how the mind can know facts—how one can bridge the absolute gulf that Plato (Plato 340 BCE/1941) and Descartes (1633/1999) drew between the mental and the physical.

Vygotsky’s social philosophy overcomes this problem by showing how interactions among people achieve shared involvement in the world. In Descartes’ system, there was no way to put together the mother’s understanding, the infant’s understanding, the physical grasp and the symbolic meaning of pointing. In Vygotsky’s analysis, the interaction between mother and infant creates the shared meaningfulness of the pointing grasp as an intersubjectively achieved unity. There is no longer any reason to ask such questions as where is the meaning of the gesture, how does the mother know the infant’s intention or whether there is common ground. These are pseudo-problems caused by trying to reduce a social phenomenon at the group unit of analysis to issues at an individual unit of analysis.

These philosophical issues are intimately related to issues of empirical methodology. They imply that certain matters should be analyzed as group phenomena and not reduced to individual psychic acts or mental representations.
As researchers, we can empirically observe new referencing gestures being created within interactions among collaborating people, particularly when their interaction is taking place via a new medium that they must learn how to use. In the analysis above, a chat posting—“What is the area of this shape?”—constitutes the participants in the chat as a group by designating them as the intended collective recipient and as the expected respondent to the question (Lerner 1993). The group is the intended agent who will work out the mathematics of the proposal to compute the area. Simultaneously, by referencing a mathematical object (“this shape”), the posting constitutes the group as a being-there-together-at-the-object—at an object that is constituted, identified, referenced and made meaningful by the group interaction.

We saw how both these aspects of being a group necessitated considerable interactional work by the participants. Before the elicited answer about area could be given in response to the question, the group had to negotiate what it as a group took the object to be. Also, it required a number of actions for group participants to co-construct the shared object and their being-there-together-at-the-object. In attempting to do this, they constituted themselves as a group and they established referential gestures and terms that took on the shared meaning of intending the new math object.

The interactional work of the group involved making use of the resources of the environment that mediated their interaction. This is particularly noticeable in online interaction. Vygotsky’s infant and mother could use fingers, gaze, touch, voice. Online participants are restricted to exchanging textual postings and to using features of the mediating software (Garcia & Jacobs 1999; Stahl 2006c). The chat participants must explicitly formulate through text, drawings or graphical references actions that can be observed by their fellow group members. These actions are also available to researchers retroactively.

The textual interactions in the chat excerpt as the cognitive actions of the group are in intimate contact with the details of the drawing as the physical intentional object. For instance, as we saw above, in the interchange in lines 13 to 16 the group attention is focused at a particularly interesting and ambiguous drawn line. Group methods of proceeding often involve adjacency pairs, sequences of utterances by different people that construct group meaning and social order through their paired unity. The meaning is constituted at the group unit of analysis by means of the interaction of the pair of utterances, not as a presumed pre-interactional meaning in the heads of individuals.

Line 13 is a bid at opening up a math proposal adjacency pair (Stahl 2006c): it offers a new step for mathematical discussion and elicits an uptake response from the rest of the group. Line 16 is the elicited response that takes up the bid with a kind of repair. It indicates that the proposed assumption is unnecessary and thereby attempts to re-establish a shared understanding of the situation.
Lines 14 and 15 form a question/answer adjacency pair inserted in the middle of the proposal pair in order to make sure that the group really is together at the same detail of their shared math object.

The issue that is worked out by the group as they look carefully at the drawing together illustrates the subtlety of abstract mathematical thinking that the group is engaged in as a group. The issue involves the lines that were drawn with the whiteboard’s rough cognitive tools for drawing and whether or not these lines coincide with lines of the grid (i.e., if the group should “assume those lines are on the blocks”). The issue is not one that is resolved by a close analysis of the actual pixels on the screen. Rather, it is a conceptual question of the meaning of those lines for the group: What do they mean in the drawing and how should they be taken by the group in its math discourse?

In being together at the lines, the group makes sense of the meaning of the lines. There is no separation of fact and meaning here—or, if there is, the group interaction engages in meaning-making processes that fluidly overcome the gulf. This is particularly important in math discourse, where rough sketches are used to represent (mean and reference) abstract objects. Maintaining a shared understanding by a group of students working in a mathematical context like this is a subtle and intricate matter.

As designers of online education, we are interested in understanding how students collaboratively create new communicative gestures or interactional methods, including ways of referencing objects for joint consideration. More generally, an interactional understanding of referencing and meaning making leads to a theory of group cognition—rather than individual cognition based on mental representations—as a basis for studying collaborative learning (Stahl 2006a).

All the technical terms like cognition, intentionality, reference, sense making, temporality and learning needed to articulate a theory of group cognition must be re-conceptualized at the group unit of analysis. In some cases, the nature of these phenomena are actually easier to see at the group level, where participants have to make things visible to each other in order to coordinate their actions as group activities, as was the case with referencing in the excerpt discussed above.

**Pedagogy of Referencing Math Objects**

Our case study suggests that cognitive tools for referencing can be important supports for group cognition and collaborative knowledge building, particularly in a setting of computer-supported collaborative mathematics.
In the investigation reported here, we tried to encourage relatively open-ended explorations of mathematical inquiry by online teams of math students. We presented them with a non-traditional form of geometry in which notions like distance, area or shortest-path have to be renegotiated—i.e., the meanings of these terms must be jointly constructed anew. While trains of inquiry can go in many directions, in a collaborative effort each step of the path may be clarified and shared. New math objects emerge and develop out of the discourse, including both geometric figures (the tricky area) and terminology (“distance along the grid”).

In this study, the analysis of a snippet of a group-cognitive process in a concrete empirical case has suggested the centrality of joint referencing to collaboration. This may serve as an additional clarification of what is meant by defining collaboration as “a continued attempt to construct and maintain a shared conception of a problem … an emergent, socially-negotiated set of knowledge elements that constitute a Joint Problem Space” (Roschelle & Teasley 1995, p. 70) and what goes into actually doing such a thing.

The persistent whiteboard serves as a “group external memory” that plays a useful role in grounding shared understanding at the scale of analysis of CSCL problem solving (Dillenbourg & Traum 2006, p. 122f), in contrast to Clark & Brennan’s (1991) psycholinguistic level. The intertwining uses of the dual workspaces of whiteboard and chat mirror the intertwining of content space and problem space that is characteristic of collaborative learning (Barron 2003, p. 310).

Given the complexity resulting from dual spaces—whether split for work vs. reflection (Fischer et al. 1998; Schön 1983) or transitory vs. persistent (Dillenbourg & Traum 2006, p. 143f)—and the concomitant substantially increased burden of coordination within the group, we can clearly see the importance of cognitive tool support for referencing from one space to the other.

Referencing in mathematical worlds has its own domain-specific characteristics and priorities. Widespread conceptions of math learning as the memorization of “math facts” or the mastery of formulaic algorithmic solutions are oriented to the routine application of arithmetic rather than to the creative process that inspires mathematicians. The history of mathematics as a branch of scientific inquiry and knowledge building is a systematic unfolding of new domains through the shared construction of new math objects, like complex numbers, fractals, curved spaces. To share these created math objects as boundary objects within their discourse community, mathematicians have had to define new vocabularies, symbols and representations for referencing objects that do not exist as such in the physical world. Referencing such abstractions presents special cognitive challenges.
People who do not understand mathematical references can scarcely be expected to share the wonder and excitement that mathematicians feel who can see what is being referenced (Lakoff & Núñez 2000). It is likely that much of the general population simply does not share the understanding of what is referenced in most mathematical proofs and discussions. Since our goal is to increase mathematical appreciation and participation through opportunities for online math discourse, we are keen to support shared referencing in our environments with effective cognitive tools.
Group Cognition in Computer-Assisted Collaborative Learning

Abstract: Recent research on instructional technology has focused increasingly on the potential of computer support to promote collaborative learning. Socio-cultural theories have been imported from cognate fields to suggest that cognition and learning take place at the level of groups and communities as well as individuals. Various positions on this issue have been proposed and a number of theoretical perspectives have been recommended. In particular, the concept of common ground has been developed to explain how meanings and understandings can be shared by multiple individuals. This essay takes a critical look at the concept of shared meaning as it is generally used and proposes an empirical study of how group cognition is constituted in practice.

Among those researchers working on computer-assisted learning, a community has emerged in the past decade known as computer-supported collaborative learning, or CSCL (Crook 1994; Dillenbourg 1999; O’Malley 1995). In an influential attempt to define this paradigm of research, Koschmann (1996b) argues that previous forms of instructional technology research “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 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 computer-assisted learning 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 for millennia become used to taking 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.

Thus the question of group cognition can be viewed as largely a methodological, rather than ontological issue: it is a call to analyze case studies of collaboration at the group unit of analysis, rather than a claim that some kind of group mind exists beyond the situated and transient group discourse itself. As Stahl (2003) argued, one can identify processes of meaning-making or knowledge-building in the interaction that cannot be attributed to any individual group members, although the participation of the individuals in the group process is necessary as sources of contributed utterances and as interpreters of the shared meaning.

In fact, analysis at the group level of description often demonstrates that even when someone learns or thinks in seeming isolation, this activity is essentially conditioned or mediated by important social considerations. This was a general claim of Vygotsky (1930/1978): that intersubjective or inter-psychological or group learning generally preceded individual or intra-psychological learning, which resulted from the internalization of what took place socially. Koschmann points out that Vygotsky—one of the principle 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 potential social development 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 by 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. Despite the attempt by these traditions within CSCL to overcome the traditional focus of educational and psychological theories on the
individual as cognitive agent, none of them have worked out a satisfactory theory of group cognition.

Stahl (2003) drew on the aforementioned and other sources to argue for taking meaning that is constructed in successful processes of collaboration as a shared group product, which is, however, necessarily 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 for most people to overcome their individualistic conceptual traditions and come to terms with group learning or group cognition. This essay is an attempt to further that effort by considering just what is meant by shared meaning and group cognition.

The Problem of Shared Meaning

The analysis by Stahl (2003) 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 group’s 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.

Stahl (2004) presented an example of how this works. The discourse transcribed there is strikingly elliptical, indexical and projective; that means that it 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, one can only attribute well-defined opinions and intentions to the individual students after one has extensively interpreted the meanings of the discourse as a whole.

As seen in the example transcript, the shared meaning was collaboratively created by the group as a whole. But the establishment of that meaning as shared involved a process of negotiation through which the individual group members had to interpret the meaning from their own personal perspectives, to display their understanding of the meaning and to affirm that meaning as shared. The collaborative process itself entailed corresponding individual processes. In a sense, one can say both that the individuals learned as a result of the group learning, and that the group could only learn by ensuring that the individuals learned.

Of course, the kind of “learning” that happens in a brief interaction is not the kind of learning that educators look for over months. It is perhaps better referred to as “knowledge building,” in which some word or utterance takes on a new shared meaning. To understand what takes place in collaborative interactions, it seems important to become clearer about the nature of shared knowledge—how it is produced, negotiated, distributed and internalized.

The major difficulty in understanding shared knowledge and group cognition is that it is habitual to attribute thoughts and intentions to individual actors—and to reduce group phenomena to actions of the individual group members. One assumes 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 to convey it to the listeners. This reveals a conflict. If meaning is socially constructed, why do researchers 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 (or may be shared first, before it can become part of an individual’s knowledge).

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 a result of individual knowledge, reducible
to knowledge held by individual thinkers or an emergent property of the group discourse as an irreducible unit for purposes of analysis. If CSCL is to be conceived as a fundamentally new educational form, rather than just a technique for fostering individual learning, than it seems that something like the third reading of “shared knowledge” needs to be explicated.

A Conflict of Paradigms

Research on learning and education is troubled to its core by the conflict of 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 (1996b), the field of CSCL is still enmeshed in the paradigm conflict between opposed cognitive and sociocultural focuses on the individual and on the group (Kaptelinin & Cole 2002). In his keynote at the CSCL ’02 conference, Koschmann (2002a) argued that even exemplary instances of CSCL research tend to adopt a theoretical framework that is anathema to collaboration. Koschmann 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. Stahl (2003) 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 BCE/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). 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 2002b; Packer & Goicoechea 2000), Stahl (2004) argued that it is more a matter of focus on the individual (cognitivist) versus group (sociocultural) 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 (Salomon 1993)) take on values along a spectrum from individual to group. The following is an attempt to characterize possible positions along this spectrum, most of which have been advocated for in the literature:

- 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.

• 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.

• 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.

• Learning is always a mix of individual & 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.

• 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.

• All human learning is fundamentally social or collaborative; language is never private; meaning is intersubjective; knowledge is situated in culture and history.

These different positions imply different answers to why CSCL is important. At one extreme of the spectrum, collaboration is only valued to the extent that it results in learning outcomes for individual minds. At the other extreme, collaborative learning can benefit a whole community of practice by developing cultural artifacts like theories. Intermediate positions may acknowledge that benefits accrue at group and individual levels in parallel, through reciprocal influences.

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 (Johnson & Johnson 1989; 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

The following list describes some representative theories that focus on the group as a possible unit of knowledge construction. Of course, each theory is itself too complex to be summarized meaningfully in a sentence, consisting of multiple texts and redefining terms like “learning” and “knowledge” in the process of developing a theory:

- **Collaborative Knowledge Building.** A group can build knowledge that cannot be attributed to an individual or to a combination of individual contributions, but that exists as textual artifacts that can be critiqued by others (Bereiter 2002; Donald 1991).
- **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 (Fischer & Granoo 1995; Resnick et al. 1991; Salomon 1993).
- **Distributed Cognition.** Knowledge can be spread across a group of people and the tools that they use to solve a problem (Hutchins 1996; Norman 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 possible nature of group knowledge.

Most of these theories hinge on the question of how it is possible for shared knowledge to be established. Despite this, none of these authors have explained how groups can learn in sufficient detail to overcome widespread resistance to thinking about learning at the group level of description.
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. It emphasized the centrality of interpretation to human existence as being engaged in the world. It 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 CSCL is, however, more focused. It is concerned with the short-term negotiation of common ground during brief 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 the presentations of Roschelle (1996) and Stahl (2004) 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 to breakdowns in such 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. This is what is proposed in the next section of this essay. But first, this alternative should be made 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 assumed that understanding (i.e., mutual belief) can never be perfect (i.e., the participants can never 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 (1991) then show 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 (1991) responds polemically to Clark & Brennan (1991) by opposing the tradition of ethnomethodology and CA to this theory of mental beliefs: Schegloff points out that Garfinkel (1967) “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), 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 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. Thus, there seems to be a group shared understanding, which is effective in the practice of the operation, but which does not correspond to the understanding of the individual participants when considered outside their working team—as Clark’s theory of common ground would have it.

Perhaps the case of the operating room (OR) 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.

Of course, the OR situation was a special case which differed in significant ways from most everyday conversation. 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 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? This is, above all, an empirical question, although it requires a clear conceptual framework for defining and interpreting the data.

### Empirical Inquiry into Group Cognitive Practices

At Drexel University, an interdisciplinary group of researchers and staff of the Math Forum @ Drexel—mathforum.org, a popular online site with resources and problems related to K-12 school mathematics—are undertaking 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 (2002a) pointed out, the analytic paradigm of that paper is ambiguous. Its focus on the problematic of convergence 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 study reported by Stahl (2004) was an attempt to analyze knowledge building at the group level by a group of five students. Stahl’s analysis was in some respects similar to Roschelle’s. Our current research project takes Stahl’s 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.

Like many studies of collaborative learning (but unlike our proposed math study), the pilot study involved face-to-face interaction with an adult mentor present. Close analysis of student utterances during an intense interaction during that study suggested that the group 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, however, a number of limitations to the study:

1. Although the mentor was quiet for the specific 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 conclusions about how much individual students understood of the group knowledge before, during or after the interaction.

To overcome such limitations, in our current 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 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.
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 discourse analysis can “make visible” that knowledge to researchers.

We are investigating not only whether computer-supported collaborative learning can construct novel group knowledge, but also what community contexts are favorable to fostering such an outcome. We are doing this by designing and implementing an experimental service in the Math Forum. Students visiting the site are invited to join small virtual teams to discuss and solve math problems collaboratively online. We analyze the interactions in these 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 five 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 or 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 what each student understood before, during and after 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). Discourse analysis is a rigorous human science, going under various names: conversation analysis, interaction analysis, micro-ethnography, ethnomethodology (Garfinkel 1967; Heritage 1984; Jordan & Henderson 1995; Sacks 1965/1995; Streeck & Mehus 2003). This method of analysis will allow us to study what takes place through the collaborative interactions. We will be looking for evidence of learning at the micro level, where shared meanings are developed and knowledge is built up as part of solving a challenging math problem.

The focus on discourse suggests 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. One way of putting it is 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 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 interpretations by other members. However, 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 (Stahl 2003).

These are questions that we will investigate 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 group knowledge
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 (Stahl 2002).

Issues for Future Investigation

While we believe that it is possible to clarify the nature of shared knowledge and group cognition by serious reflection upon the existing theoretical discussions and case studies that touch on these concepts (many of which have been referenced in this essay), we are convinced that significant progress and convincing arguments will require further empirical research, such as that proposed in the online Virtual Math Teams project.

Collaborative success is hard to achieve and probably impossible to predict. CSCL represents a concerted attempt 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 not visually co-located. 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, 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, we are adapting a successful math education service to create conditions that will likely be favorable to the kind of interactions that we want to study. We must bring together groups of 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 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 based on 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 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 of group knowledge presents an enormous practical barrier to collaborative learning. Because students and teachers generally 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.
Studies of computer-supported collaborative learning have begun to explore processes of online group cognition—such as small-group methods of problem solving—and how they can be mediated by various technological and interactional mechanisms to promote academically productive discourse. This essay first presents (1) an analysis of co-presence as a foundational aspect of online interaction in an excerpt of chat discourse. Based on how the students in this excerpt actually interact, it develops (2) a notion of intersubjective shared understanding as necessary for the possibility of collaborative knowledge-building dialog. The essay concludes with (3) a discussion of consequences for the design of computer support of academically productive online group cognition.

**An Excerpt of Computer-Supported Discourse**

The studies of digital interaction by virtual math teams presented in (Stahl 2009) adopt an ethnomethodological interest in how interaction is actually carried out in particular online contexts. They assume that the member methods or group practices of computer-mediated interaction developed by small groups of students may differ significantly from commonsense assumptions of researchers based on experience with face-to-face interaction. If this is true, then it is important to explore actual instances of digital interaction before designing interventions in such settings.

This section reviews how a team of three students collaboratively achieved a cognitive accomplishment as a distributed online group. The log of their
interaction makes visible mechanisms by which academically productive discourse can arise naturally in settings of “computer-supported collaborative learning,” or CSCL (Stahl et al. 2006). The data analysis presented in this initial section is not intended as an illustration of pre-existing theories; rather, the theory in the next section emerges from this and similar data.

“Wait…. I don’t really see”—Establishing Co-presence

Figure 1 shows a screenshot of the Virtual Math Teams (VMT) software environment, being used by three middle-school students. They volunteered to participate in this online, synchronous math activity with other students from around the world. The students are collaboratively investigating mathematical patterns (combinatorics) related to sequences of geometric figures. In the lower right of the whiteboard is a stair-step pattern of blocks remaining on the board from their previous day’s session. Currently, the students are considering a pattern of regular hexagons, which they will visualize in a grid of triangles they construct in the lower left.
VMT is a prototypical CSCL environment, with a text-chat tool integrated with a shared whiteboard. Table 1 shows a chat excerpt. Three students—whose online names are 137, Qwertyuiop and Jason—are chatting.
Table 1. Log of the chat excerpt.

<table>
<thead>
<tr>
<th>line</th>
<th>time</th>
<th>student</th>
<th>chat post</th>
</tr>
</thead>
<tbody>
<tr>
<td>705</td>
<td>19:15:08</td>
<td>137</td>
<td>So do you want to first calculate the number of triangles in a hexagonal array?</td>
</tr>
<tr>
<td>706</td>
<td>19:15:45</td>
<td>qwertyuiop</td>
<td>What's the shape of the array? a hexagon?</td>
</tr>
<tr>
<td>707</td>
<td>19:16:02</td>
<td>137</td>
<td>ya</td>
</tr>
<tr>
<td>708</td>
<td>19:16:15</td>
<td>qwertyuiop</td>
<td>ok...</td>
</tr>
<tr>
<td>709</td>
<td>19:16:41</td>
<td>Jason</td>
<td>wait-- can someone highlight the hexagonal array on the diagram? i don't real</td>
</tr>
<tr>
<td>710</td>
<td>19:17:30</td>
<td>Jason</td>
<td>hmmm... ok.</td>
</tr>
<tr>
<td>711</td>
<td>19:17:43</td>
<td>qwertyuiop</td>
<td>oops</td>
</tr>
<tr>
<td>712</td>
<td>19:17:44</td>
<td>Jason</td>
<td>so it has at least 6 triangles?</td>
</tr>
<tr>
<td>713</td>
<td>19:17:58</td>
<td>Jason</td>
<td>in this, for instance</td>
</tr>
<tr>
<td>714</td>
<td>19:18:53</td>
<td>137</td>
<td>how do you color lines?</td>
</tr>
<tr>
<td>715</td>
<td>19:19:06</td>
<td>Jason</td>
<td>there's a little paintbrush icon up at the top</td>
</tr>
<tr>
<td>716</td>
<td>19:19:12</td>
<td>Jason</td>
<td>it's the fifth one from the right</td>
</tr>
<tr>
<td>717</td>
<td>19:19:20</td>
<td>137</td>
<td>thanks.</td>
</tr>
<tr>
<td>718</td>
<td>19:19:21</td>
<td>Jason</td>
<td>there ya go :)</td>
</tr>
<tr>
<td>719</td>
<td>19:19:48</td>
<td>137</td>
<td>er... that hexagon.</td>
</tr>
<tr>
<td>720</td>
<td>19:20:02</td>
<td>Jason</td>
<td>so... should we try to find a formula i guess</td>
</tr>
<tr>
<td>721</td>
<td>19:20:22</td>
<td>Jason</td>
<td>input: side length; output: # triangles</td>
</tr>
<tr>
<td>722</td>
<td>19:20:39</td>
<td>qwertyuiop</td>
<td>it might be easier to see it as the 6 smaller triangles.</td>
</tr>
<tr>
<td>723</td>
<td>19:20:48</td>
<td>137</td>
<td>like this?</td>
</tr>
<tr>
<td>724</td>
<td>19:21:02</td>
<td>qwertyuiop</td>
<td>yes</td>
</tr>
<tr>
<td>725</td>
<td>19:21:03</td>
<td>Jason</td>
<td>yup</td>
</tr>
<tr>
<td>726</td>
<td>19:21:29</td>
<td>qwertyuiop</td>
<td>side length is the same...</td>
</tr>
<tr>
<td>727</td>
<td>19:22:06</td>
<td>Jason</td>
<td>yeah</td>
</tr>
<tr>
<td>728</td>
<td>19:22:13</td>
<td>Jason</td>
<td>so it'll just be x6 for # triangles in the hexagon</td>
</tr>
<tr>
<td>729</td>
<td>19:22:19</td>
<td>137</td>
<td>each one has 1+3+5 triangles.</td>
</tr>
<tr>
<td>730</td>
<td>19:22:23</td>
<td>Jason</td>
<td>but then we're assuming just regular hexagons</td>
</tr>
<tr>
<td>731</td>
<td>19:22:29</td>
<td>qwertyuiop</td>
<td>the &quot;each polygon corresponds to 2 sides&quot; thing we did last time doesn't work</td>
</tr>
<tr>
<td>732</td>
<td>19:23:17</td>
<td>137</td>
<td>it equals 1+3+...+(n+1) because of the &quot;rows&quot;</td>
</tr>
<tr>
<td>733</td>
<td>19:24:00</td>
<td>qwertyuiop</td>
<td>yes- 1st row is 1, 2nd row is 3...</td>
</tr>
<tr>
<td>734</td>
<td>19:24:49</td>
<td>137</td>
<td>and there are n terms so... n(2n/2)</td>
</tr>
<tr>
<td>735</td>
<td>19:25:07</td>
<td>137</td>
<td>or n^2</td>
</tr>
<tr>
<td>736</td>
<td>19:25:17</td>
<td>Jason</td>
<td>yeah</td>
</tr>
<tr>
<td>737</td>
<td>19:25:21</td>
<td>Jason</td>
<td>then multiply by 6</td>
</tr>
<tr>
<td>738</td>
<td>19:25:31</td>
<td>137</td>
<td>to get 6n^2</td>
</tr>
</tbody>
</table>

In line 705, student 137 poses a math question of potential interest to the small group. Then Qwertyuiop seeks to understand the math shape that 137 proposed. Qwertyuiop next draws the grid of triangles to see if he understands what 137 means by “hexagonal array.”

Jason effectively halts the discussion (line 709) to seek help in seeing the hexagonal form that 137 and Qwertyuiop see. Jason’s posting is designed to bring the group work to a halt because he does not see what 137 and Qwertyuiop are talking about. This is an important collaboration move, asking the others to clarify what they are talking about. Jason is referring to the group meaning-making process, and halting it so he can fully participate.

Jason phrases his request in terms of “seeing” what the others “mean.” This seeing should be taken literally, in terms of vision and graphics. Jason asks
the others to “highlight the hexagonal array on the diagram” so he can see it in the graphics.

137 outlines a large hexagon with extra lines, as shown in Figure 2. This provides what Jason needs to be part of the group problem-solving effort. Jason not only says, “Okay” but he contributes a next step (line 712) by proposing a math result and giving a visible demonstration of it with a highlighted small hexagon. Giving a next step shows understanding and also takes the idea further. Jason points from his chat posting. Note the green rectangle highlighting a small hexagon and the line connecting Jason’s current chat posting (713) to this highlighted area; this is an important feature of the VMT system supporting online pointing or deixis. Pointing is a critical function for shared understanding—and must be supported explicitly in a digital environment, where bodily gestures are not visible to others.

After Jason draws the visual attention of the other participants to a particular example of a smallest hexagon, consisting of 6 triangles, 137 asks Jason how to change the color of lines in the whiteboard. In line 715, Jason responds and 137 changes the color of the lines outlining the larger hexagon. Color becomes an effective method for orienting the team to a shared object. This use of colored lines to help each other see focal things in the whiteboard will become an important group practice in the team’s continuing work. In line 719, 137 outlines a larger hexagon, with edge of 3 units.

At this point, the group has established an effective co-presence at a mathematical object of interest. Through a variety of interactional practices—which the group members have adapted from past experiences or constructed on the spot—the group has regulated its interaction and focused its common vision into a “being-there-together” (Stahl et al. 2011) with the object that they have constituted as an hexagonal array. The group is now in a position to explore this object mathematically.

“Like this....”—Building Intersubjective Shared Understanding

In line 720, Jason explicitly proposes finding a formula for the number of elemental triangles in a hexagonal array with side-length of N. Qwertyuiop suggests a way of seeing the hexagonal array as consisting of 6 identical sectors, which he ambiguously refers to as “the 6 smaller triangles.” 137 checks what Qwertyuiop means by asking him, “Like this?” and then dividing up the large hexagon with 3 red lines, forming 6 triangular forms inside of the blue outline (see Figure 3). This is a move by Qwertyuiop to see the representation of their problem as a much simpler problem. As Jason notes, now they only have to compute the number of elemental triangles in each of the 6 identical triangular sectors and then multiply that result by 6 to get the total. Furthermore, the
simpler problem can be solved immediately by just looking. As Jason says, each sector has 1+3+5 triangles. The human eye can recognize this at a glance, once it is properly focused on a relevant sector.

The important mathematical problem-solving move here is to see the problem in a new way. Qwertyuiop sees the hexagon as a set of 6 symmetrical sectors. The important discourse move is to share this new view with the team. This is accomplished collaboratively in lines 722-725: Qwertyuiop proposes a new way of seeing the array; 137 outlines it, using their new technique of colored lines; and Jason aligns with them. They each participate in seeing the same thing (seeing the hexagon as composed of 6 triangles), in demonstrating to each other that they see this new way, and then in building on each other to count the small triangles visually. They thereby collectively go beyond the co-presence of seeing the same thing to actually build knowledge about the object. This group knowledge is intersubjectively shared understanding of the mathematical structure of the object. Through the sequence of steps outlined above, the members of the group have articulated an understanding that they share as a result of their co-presence and of their shared textual and graphical actions.

“To get $6n^2$”—Accomplishing Group Cognition

Note in the chat how the three students build on each other to construct the general formula for any size array: $6n^2$. Having collaboratively deconstructed the complicated problem into visually simple units, they now take turns in reconstructing the problem symbolically and for any size hexagon. They are able to work on this together because of their co-presence, which allows them to orient to the same objects, with a shared understanding of the terms (e.g., “hexagonal array,” “side length”), graphics (colored border lines), procedures (divide into 6, then multiply by 6) and goals (“find a formula”).

Having counted the number of triangles in the array during this excerpt, the students will next want to count the number of line segments. This is more complicated, but the group will extend the methods we have just observed to accomplish their task. Taking advantage of multiple symmetries, they will use colored lines to break the pattern down into visually simple patterns, outline specific focal areas and attend to shared objects, where their optical systems can do the counting. Some of the smaller units are harder to visualize and there are issues of possible overlap among the sectors. But using the skills we observed and developing those skills incrementally, the group will succeed in achieving a sequence of cognitive accomplishments (for a detailed analysis, see Çakir & Stahl 2013).
Intersubjective Shared Understanding

The establishment of shared understanding in a small group through co-attending to shared objects is essential for collaboration (Evans, Feenstra, Ryon & McNeill 2011; Mercer & Wegerif 1999). However, in an online context the usual techniques of body positioning, gaze and explicit pointing with fingers are not available for creating and maintaining shared attention. Virtual teams must invent new methods to coordinate attention or make use of special tools in the software that may be provided to support this.

Previous VMT studies have analyzed cases in which small groups of online students have developed methods for creating, maintaining and repairing shared understanding—similar to what was seen in the previous section. For instance, small groups working in the VMT environment have:

• Co-experienced a shared world (Stahl et al. 2011) by developing shared group practices (Medina et al. 2009; Stahl 2011b)

• Used the posing of questions to elicit details needed to establish and confirm the sharing of understandings (Zhou et al. 2008).

• Built a “joint problem space” (Teasley & Roschelle 1993)—i.e., a shared understanding about a set of topics—with ways of referencing them—an “indexical ground” (Hanks 1992)—that is shared and supports co-attending (Sarmiento & Stahl 2008).

• Developed group methods for bridging across temporal breaks in interaction to reestablish a group memory or shared understanding of past events. (Sarmiento & Stahl 2007)

• Repaired their shared understanding in the face of breakdowns (Stahl, Zemel & Koschmann 2009).

• Integrated text chat and sequences of whiteboard actions to communicate complex mathematical relationships (Çakir et al. 2009).

• Solved math problems by proceeding through logical sequences of steps collaboratively (Stahl 2011a).

The analysis of the excerpt of interaction presented above and these other studies of VMT have identified the following features of the mediation of digital interaction: co-presence, intersubjective shared understanding and group cognition. We will now review the theoretical articulation of these three features as foundations that make possible the goals of academically productive discourse.
Co-presence

Co-presence—through co-attending as a basis for shared understanding—by a small group includes many of the basic features of an individual attending to and interpreting an object of interest. Attending to something involves focusing on it as the foreground object, assigning everything else to its background context (Polanyi 1966). For instance, the students in the excerpt above foreground a specific hexagon against the background of the larger array of lines by coloring its outline or highlighting it with the pointing tool. Attending to an object involves seeing it “as” something or some way (Goodwin 1994; Heidegger 1927/1996; Wittgenstein 1953). Co-attending supports a shared interpretation, viewing or understanding by creating co-presence attending to a shared object in a shared world in a shared way. For instance, the students view the larger hexagon “as” a set of six triangular sectors by visually dividing the hexagon with red lines that outline the sectors and by texting, “it might be easier to see it as the 6 smaller triangles.” (Note that the terminology Qwertyuiop naturally uses here explicitly involves “to see it as....”)

Intersubjective Shared Understanding

One can distinguish two paradigms of shared understanding. A rationalist paradigm assumes that individuals each have a stock of propositions in their minds that represent their current beliefs or opinions. The corresponding conception of shared understanding starts from individual understanding of two people and tries to establish equivalence of one or more propositions they hold. This is sometimes called “cognitive convergence,” where the goal is to converge the two mental models: Sharing as mutual giving.

The alternative paradigm of shared understanding—exemplified by the analysis in this essay—starts from the shared world and a view of intentionality as consciousness of an object, rather than as a mental construct by an ego. This is the view of situated and distributed cognition, where individuals are situated in and active with a shared, intersubjective world consisting of meaningful objects for which they care: Sharing as doing together.

Twentieth-century philosophy from Hegel (1807/1967) and Husserl (1936/1989) through Marx (1858/1939), Heidegger (1927/1996), Sartre (1968), Merleau-Ponty (1945/2002) and Wittgenstein (1953) has rejected the starting point of a transcendental ego in favor of consciousness as a social and fundamentally shared phenomenon. Now, even at the neuron level, the discovery of mirror neurons points to a physiological, specifically human, basis for shared cognition (Gallese & Lakoff 2005). We can immediately experience the world through the eyes and body of other people. We can feel the pain if we see another person’s body hurt. As Wittgenstein (1953) argued in other ways,
there is no such thing as private feelings of pain or of private meanings of language: We are co-present in an intersubjectively shared and commonly understood world.

**Group Cognition**

Vygotsky (1930/1978) claimed that intersubjective (group) cognition precedes intra-subjective (individual) cognition. He conducted controlled experiments to show that children were able to accomplish cognitive tasks in collaboration with others at an earlier developmental age than they were able to accomplish the same tasks on their own. Individual-cognitive acts are often preceded by and derivative from group-cognitive acts. For instance, individual reasoning or action (dividing a figure, coloring a border) by a student in the VMT data may be based upon earlier group practices. According to Vygotsky, individual mental thinking is fundamentally silent self-talk. Thus, individual-student reasoning can often be seen as reflective self-talk about what the group accomplished. In such cases, self-reports about individual cognition—through think-aloud protocols, survey answers or interview responses—are what Suchman (2007) refers to as post-hoc rationalizations. They are reinterpretations by the individual (responsive to the interview situation) of group cognitions. In this reading of Vygotsky, group cognition has a theoretical priority over individual cognition. If one accepts this, then the theoretical analysis of shared understanding and the practical promotion of it become priorities. The emerging technologies of networked digital interaction provide promising opportunities for observing and supporting the establishment of shared understanding in online educational environments.

Based on experiments in computer support of small-group knowledge building from 1995-2005, I proposed the construct of *group cognition* (Stahl 2006a) to begin to define the relevant focus on group-level cognitive achievements; analyses of studies from 2006-2009 (Stahl 2009) continued to explore the practicalities of supporting group-level cognition.

Group cognition is not a physical thing, a mental state or a characteristic of all groups. It is a unit of analysis. What it recommends is that analysts who are studying digital interaction should look at the small-group unit of analysis (Stahl 2010). Too often, collaborative learning researchers reduce group-level phenomena either to individual psychological constructs or to societal institutions and practices (Stahl 2013d). But, as we have seen in the excerpt, there are group methods and processes taking place at the small-group unit of analysis that are not reducible to the mental behaviors of an individual or to the institutions of a community. For instance, the three students collaboratively solved their problem through a sequence of postings that elicit and respond to each other. Qwertyuiop proposed the view of the hexagon as 6 sectors; 137 summed the series of triangles in one sector to n²; Jason provided the answer by
multiplying the value for one sector by the number of sectors. The result was a group product of the group interaction. If one student had derived this result, we would call it a cognitive achievement of that student. Since the group derived it, it can be called an achievement of group cognition. This does not mean there is some kind of “group mind” at work or anything other than the interaction of the three students. Rather, it means that the analysis of that cognitive achievement is most appropriately conducted at the group unit of analysis, in terms of the interplay of the posting and drawing actions shared by the group.

The absolute centrality of public discourse and shared understanding to the success of group cognition—successful knowledge building at the group level—in the context of digital interaction implies the need for productive forms of talk within the group. Digital environments to support collaborative knowledge building must be carefully designed to foster co-presence, intersubjective shared understanding and group cognition through supporting academically productive talk.

**Consequences for Computer Support of Discourse**

The theory of academic talk has been primarily oriented toward affecting individual cognition in contexts of face-to-face instruction. Accordingly, it is based on the paradigm of cognitive convergence, trying to guide individual students to converge their individual understandings with the understandings of other students, the teacher or the community. In the alternative paradigm presented in this chapter for group cognition in online contexts, one tries to maintain and build on intersubjective shared understanding and then guide the group of students to articulate clearly, explicitly and scientifically its largely tacit shared group understanding.

Computer technology suggests many tools for supporting group cognition. Computers can provide computational supports, such as spreadsheets and graphing calculators, for assisting individuals and groups in computing tasks. They can provide digital media for communication (text, audio, video, drawing, mapping, etc.). They can provide domain-specific visualizations and work environments, such as the multi-user dynamic-geometry system that VMT has recently incorporated (Stahl 2013e; Stahl & Powell 2012). Perhaps most importantly, computers allow people to interact with others around the world.

A particularly intriguing potential of computer technology is to have software agents that interact directly with groups of people—in analogy with
human teachers or tutors who support face-to-face groups (see chapters by Gillies and Webb, et al., this volume). For instance, an accountable-talk agent could interact with students to prompt them to engage in accountable-talk moves. As promising as this sounds, it is equally problematic. Detailed studies of online interaction by small groups of students in the VMT environment show that students are creative at adapting their subtle linguistic skills to the characteristics of online media. They are able to achieve impressive accomplishments of group cognition in exploring mathematical phenomena through dialogic interaction. However, this interaction is fragile and easily disrupted by external interventions of educators and surrogate educators. In particular, software agents—designed to guide groups of students to maintain focus and to engage in productive discourse—can be particularly distracting.

This concluding section of the essay will address three issues related to the potential of using software agents to promote accountable talk within small online groups of students: invasiveness, automated agency and over-scripting—which respectively threaten to disrupt co-presence, shared understanding and group cognition.

**Invasiveness**

We have seen that a primary cognitive need is to maintain focal attention; for group cognition, this means maintaining shared attention. Software agents and other scaffolds can distract attention from what the group has created as its focus. An automated agent might raise issues at inopportune moments, interrupting the flow of discourse and group problem solving. We call this possibility “invasiveness.”

If software agents are introduced as participants in a group interaction and their status is left ambiguous in order to catch the fancy of students, this will likely raise false expectations. Students may assume that the agent knows answers, has teacher powers or understands student intentions. The agent can itself become the focus of attention, distracting from both the peer interaction and the problem solving.

Collaboration involves following the lead of the students (individually and as a group); but software agents are not good at understanding student thinking. In experiments investigating the use of software agents in the VMT environment to scaffold and guide group cognition, we have seen how problematic accountable-talk agents can be (Stahl 2013a). Agents were sometimes distracting, confusing, disruptive. The agents did not always listen well to the students or follow their lead. While some of the problems in our initial experiments with agents were substantially reduced through re-programming the agents in response to detailed analyses of the results by multiple researchers (Suthers,
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Lund, Rosé & Law 2013), agents may be ultimately incapable of being well “situated” in a group’s shared world. Since they are not co-present, attending to the shared object of attention in human ways, but are following generic algorithms designed outside of the current context of interaction, their contributions can disrupt the delicate focus of group co-attention.

Automated Agent

Agents and other automated techniques for guiding student groups to achieve academic goals are often modeled on the role of an excellent teacher. But even trained, experienced teachers find the task of orchestrating student discussion overwhelming. Teachers should ideally anticipate student misconceptions, monitor their ideas and have them presented to the class in a strategic sequence (Stein, Engle, Smith & Hughes 2008). This requires a shared understanding by the teacher of the students’ articulations of ideas.

It is unlikely that software agents will soon be able to effectively engage in anticipating, monitoring, selecting, sequencing and making connections between student responses. It is not just a matter of the high required level of sophistication in understanding the students. In theory, it is questionable whether software agents can ever participate as human peers in small-group interaction. They cannot be situated in the world or understand meaning like humans—largely based on human bodily presence in the physical world (Lakoff 1987) and intersubjective experiences (Vygotsky 1930/1978).

Suchman (2007p. 179) derived “three outstanding problems for the design of interactive machines” in her empirical study of interactions with intelligent help systems in copier machines. These focused on the lack of a shared understanding between the machines and the humans. Suchman stressed that the limits of software supports should be made very clear to users, to avoid unrealistic expectations that lead to problems of interaction with the systems. While it is possible to address some of these concerns, it is probably important to make explicit to the users the limits of agents and other software functions. For instance, anthropomorphizing the agent with a human-sounding name and having the agent use colloquial-sounding speech forms may be counter-productive.

Over-scripting

A danger of automated guidance and scripted support (Kobbe et al. 2007), such as prompts to be answered, is that they miss the engagement of when a listener really wants an explanation. Dillenbourg (2002) noted the problem of scripted agents distracting from the student-centered nature of collaborative learning; they may appear superficially collaborative, but may fail to trigger the cognitive,
social and emotional mechanisms that are expected to occur during collaboration. If academic discourse moves are not well situated in student discourse, the effect may be disruptive to authentic group-cognitive processes.

The following implications for research on the computer support of academically productive discourse and for the design of effective supports follow from the discussion in this chapter:

• It is possible to observe and analyze in chat logs how online small groups establish co-presence, maintain intersubjectivity and accomplish group-cognitive tasks. This can often reveal cognitive processes and the effects on them of different media more clearly than in studies of individuals or face-to-face groups.

• Digital collaboration environments can support co-attention, shared understanding and group cognition in online modes that are essentially different from situations of physical embodiment. However, this requires careful design of technology, pedagogy and interventions based on iterative trials.

• Usage analysis is needed to compare the results of different approaches to the use of mechanisms such as software agents or other scaffolding. The results are often unintuitive, since they may differ from analogous effects in the context of individual cognition or face-to-face interaction.
References


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Brentano, F. (1874). *Psychologie vom empirischen standpunkte [psychology from an empirical standpoint]*. Leipzig, Germany.


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http://ijcscl.org/_preprints/volume1_issue1/fuks_pimentel_lucena.pdf


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