Computer-Supported Collaborative Learning

Gerry Stahl *Editor*

Theoretical Investigations

Philosophical Foundations of Group Cognition

Springer

Computer-Supported Collaborative Learning Series

Volume 18

The *Computer-Supported Collaborative Learning Book Series* is for people working in the CSCL field. The scope of the series extends to 'collaborative learning' in its broadest sense; the term is used for situations ranging from two individuals performing a task together, during a short period of time, to groups of 200 students following the same course and interacting via electronic mail. This variety also concerns the computational tools used in learning: elaborated graphical whiteboards support peer interaction, while more rudimentary text-based discussion forums are used for large group interaction. The series will integrate issues related to CSCL such as collaborative problem solving, collaborative learning without computers, negotiation patterns outside collaborative tasks, and many other relevant topics. It will also cover computational issues such as models, algorithms or architectures which support innovative functions relevant to CSCL systems. The edited volumes and monographs to be published in this series offer authors who have carried out interesting research work the opportunity to integrate various pieces of their recent work into a larger framework. Book proposals for this series may be submitted to the Publishing Editor: Melissa James. E-mail: melissa.james@springer.com.All books in the series are available at 25% discount to ISLS: International Society of Learning Sciences (http://www.isls.org).

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To Carol Bliss, for her love and support during these investigations

Foreword

At present, more than at any other time, we think as individuals, as groups, as cultures, and as a species, mediated by powerful tools that yoke the thinking of people around the world, if loosely. Never before in human history has most of the human species been linked by instant telecommunication, nor have we had planetary-scale access to information. While the digital divide remains, a tipping point has been crossed; the International Telecommunications Union estimates that the portion of the human race using the Internet crossed 50% sometime in 2017–2018[1]. These observations are not new. What is new is the need to come up with coherent ways to reconceptualize some very basic ideas in this new reality, including knowledge, research, and learning. In this context, the field of computer-supported collaborative learning, and this book series, offers some important insights.

There are narrow and broad framings of computer-supported collaborative learning. The narrower framing, focused on the intersection of "computer-supported," "collaborative," and "learning," reflects the initial impetus behind much of the work in the field. How could we use the power of new technologies to support innovative pedagogies where learners work together? As Stahl nicely points out in his Introduction, the ideas and people gelling around this possibility were hard to concisely circumscribe or define: Is it a paradigm? A vision? In its narrower conception, CSCL is simply a sub-sub-area of applications of educational technology. However, the particular group of people working in this area and who carried the banner "CSCL" explore much deeper issues.

Unique to the vision described by Stahl is an opportunity to define a much broader perspective, one that unpacks decades- or centuries-old assumptions about thinking, learning, and knowing and the epistemologies we use to explore those assumptions. This volume helps bring forth how studying this one narrow context—teaching kids to learn through technology-supported collaboration—can help us develop philosophical and practical approaches to new ways of understanding the relationship between information and meaning, between the psychological versus the social and cultural sciences, and between our philosophies of science, our sciences of learning, and our models for growing, sharing, and perpetuating knowledge.

There is a dialectic in the field of CSCL, one which is illustrated by both this book series and the journal from which this volume draws. In CSCL there is a constant ebb and flow between what you might call on the one hand the science, or better yet, the natural philosophy, of learning and collaboration, and on the other hand the practical wisdoms encountered by inventing, designing, reforming, and implementing new possibilities for knowledge and learning with the latest technologies. In many cases the dialectic produces astonishing results, not because of some outrageously successful teaching strategy, or because of some thunderous research finding on discourse or learning, but *because the dialectics help us reframe basic assumptions about what it means to know in a global, networked knowledge society*. Other volumes in the series have helped illustrate this in the past, including notably Stahl's (2006; 2009) earlier monumental work on group cognition which helped reframe the

[1] https://www.itu.int/en/ITU- D/Statistics/Documents/facts/ICTFactsFigures2017.pdf

question of "How individual is knowledge anyways?" or the edited volume by Suthers, Lund, Rosé, Teplovs & Law (2013) on productive multivocality which helped reframe the question "To what extent and how is conversation actually knowledge, and knowledge actually conversation?"

This book is in a somewhat unusual format, for important reasons. As a juxtaposition of classic articles from the journal and commentary, it is itself an example of (hopefully productive) multivocality. However, to assume it's simply a "greatest hits" volume that rehashes old ground would be to misunderstand its contribution. The difficulty in CSCL of synthesizing a common theoretical basis on which to build, a paradigm in the Kuhnian sense, an orthodoxy but also a cumulation, does relate to the ways in which CSCL is an interdisciplinary crossroads, and in which researchers are drawing eclectically on many traditions in ways that have not been solidified. But this is not simply a case of "just wait a few more decades and we'll have this sorted out into something neat and tidy and paradigmatic." Rather, it is an example of the field of CSCL struggling with, as the tech startups say, "eating your own dogfood." If knowledge is socially constructed, if we learn in the middle spaces between monologue and dialogue, if our understandings of knowledge contest both linear, accretive positivism, and kaleidoscopic but subjective interpretivism, then we need to question what forms our scholarly output can take.

This book extends and builds on Wittgenstein's idea of *investigations*. The book is a learning tool which invites the reader along on a journey that invites not only apprehension of prior scientific, philosophical, and design work but also a reconstruction and co-construction of knowledge. Stahl consistently enhances the work by others in the field with his own research legacy in the VMT project, bringing his own inimitable voice to the analysis. Is it a summary of what *ijCSCL* has produced? Or is it a masterclass in building theories that take into account new models of knowledge (including new roles for the academics most likely reading these words)? I argue it is both: a summation and an invitation to think along with one of the most qualified guides to this way of studying and fostering thinking and learning that we happen to call CSCL.

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Brooklyn, NY, USA Christopher Hoadley

Introducing Theoretical Investigations

By compiling his aphoristic *Philosophical Investigations*, Wittgenstein (1953) provided a provocative image of how philosophy could apprehend the world—in particular how it should understand language about the world. Just as Wittgenstein believed that a certain form of conceptual analysis was needed in philosophy, I am convinced of the relevance of certain kinds of theoretical reflection to the burgeoning field of computer-supported collaborative learning (CSCL). In founding and editing the *International Journal of Computer-Supported Collaborative Learning* (*ijCSCL*)—as a collective effort with many leading researchers from around the world—I intended to craft a venue for CSCL researchers to publish theoretical reflections on their work and on the nature of computer-supported collaborative learning. In addition, I always tried to derive theoretical insights from my own research, with its analysis of recorded student discourse.

In the spirit of Wittgenstein's collection of deliberations, I now assemble highlights of the journal and of my writings that I believe can contribute to an understanding of concepts and themes central to the field of CSCL. Wittgenstein's presentation was self-consciously anti-systematic. His paragraphs (like Einstein's transformative papers in physics) primarily pose "thought experiments," which tend to problematize established ways of thinking that have become second nature. Similarly, the Investigations of the present volume do not intend to lay out a detailed roadway for educational transformation or a logical edifice of theory. Rather, they hope to question outmoded assumptions and stimulate creative exploration in CSCL theory, methodology, and practice—like Wittgenstein providing examples of a different kind of theory. However, in distinction from the thought experiments of Wittgenstein's philosophy, the *ijCSCL* papers and my own research reports are firmly grounded in analysis of empirical interaction data.

Introducing Part I

Looking over the collection of papers collected for this volume of *Theoretical Investigations*, I perceive an emergent vision of CSCL, quite distinct from traditional educational research. I have therefore written two new introductory essays to provide an overview that suggests this vision and that connects it to theoretical concepts. These two essays constitute Part I, a synopsis and foreword to this volume.

- The first of these essays [Investigation 1] argues for a particular vision of CSCL, centered on a specific paradigm of collaborative learning, which is expanded by the sequence of *ijCSCL* papers [Investigations 3-14] that constitute Part II of this volume.
- The second essay [Investigation 2] reviews contributions to a theory of group cognition as foundational for CSCL research and practice. The papers covered by this essay [Investigations 15-25] are gathered from reports of the Virtual Math Teams (VMT) research project I directed. These papers constitute Part III of this volume.

The impetus driving the research field of CSCL has been evolving over several decades. However, the multifaceted knowledge required to implement CSCL pedagogy widely in schools was not available until now. Widespread assumptions (e.g., Schwarz and Wise, 2017) to the contrary, elements of such knowledge now largely exist—albeit in a preliminary, fractured, distributed, and uncoordinated manner. For instance, much of the knowledge needed for educational transformation is described, pointed to or illustrated in past volumes of *ijCSCL*. Unfortunately, however, some of the most innovative or penetrating analyses published there have not been further pursued or integrated with each other and with the accepted wisdom of the CSCL field. The present compendium of selected papers from *ijCSCL* is an attempt to substantiate this claim that the necessary components are available and to indicate a possible path forward to implementing a CSCL vision.

The view that students should be active learning agents is as old as our culture, enunciated by Socrates and Buddha, for instance. Over a century ago, Dewey argued for a progressive-inquiry approach in modern public schools—although, despite widespread recognition, his approach had limited impact on schooling. CSCL was founded to pursue a potential to transform learning from the memorization of facts instructed by authorities to inquiries of student groups assembled and supported by networked computer technologies. Still today, many people conduct research or introduce classroom interventions that they call CSCL, but that lack the elements that we have discovered to be central to effective collaborative learning. It is not sufficient to place groups of students together with arbitrary computer communication apps; one must design, identify, and support the required processes and practices—such as intersubjective meaning making and mediated knowledge building—for establishing a culture of group inquiry and collective knowledge building.

Introducing Part II

The publications selected for this volume from *ijCSCL* build upon historical sources and early CSCL investigations. They suggest: how to simultaneously focus CSCL theory and broaden the field's scope; how to analyze the processes of collaborative learning and mediation of group cognition by computer artifacts or supports; and how to develop innovative technological tools and educational infrastructures to facilitate collaborative knowledge building. Accordingly, they transform and potentially integrate elements of CSCL theory, methodology, and practice that can contribute to an ambitious effort to realize the CSCL vision on an international scale.

The papers included here from *ijCSCL* all emerged out of CSCL labs around the world. Significant CSCL investigations generally require teams of researchers, pooling different expertise and perspectives on cognitive theory, analytic methodology, and educational practice. They often involve consortia of labs. However, the effort to go beyond the scattered research efforts of CSCL to date and to implement the long-range vision in schools would require an even greater collaboration of researchers and educators—one on a global scale. The present volume aims to motivate the claim that this is possible through a review of the central points of selected investigations published in *ijCSCL* and reproduced here. The overview in Investigation 1, written for this volume, indicates how a synthesis of these proposals for CSCL theory, methodology, and practice could allow us to reach toward implementation of a CSCL vision. The effort required for achieving this CSCL vision would involve a global collaboration, supported by computer technologies and funded by progressive political will.

As founding editor (with Friedrich Hesse and a distinguished Board) of *ijCSCL* from 2006 through 2015, I selected favorite articles for this volume and commented on them from the perspective of influences on my own evolving understanding of CSCL. I include some articles related to the VMT project, which is the CSCL research I know firsthand. Several of the other publications represent the work of leaders in the field of CSCL research. Many of these articles were among the most cited and

downloaded publications in *ijCSCL*. I selected those that have a strong theory focus and are suggestive for implementing the CSCL vision. There are, of course, many other insightful theoretical papers available in *ijCSCL*; it was not possible to include them all in this volume. I hope this compilation will stimulate readers to return to early *ijCSCL* issues to unearth other gems.

Throughout the history of CSCL, there has been a tension between various paradigms of research, colloquially referred to as "quantitative" versus "qualitative." The thrust of this collection of papers is that the defining characteristic of CSCL methodology should not be the genre of techniques applied in data analysis but a focus on small-group interactions. The focus on the group level is definitive of collaborative learning or knowledge construction in CSCL.

In addition, "socio-cognitive" and "socio-cultural" approaches have often been contrasted. The vision arrived at in this volume moves beyond viewing individual cognition (thinking) as peripherally affected by its social context to considering human cognition as itself an interpersonal, social, or small-group phenomenon, evolving in a biological and cultural background. Today, cognition incorporates a tightly entangled complex of external memories, mediating artifacts, communication partners, and networked interactions. So conceptualized, collaborative learning is no longer a niche educational activity subservient to the needs of individual minds but a foundational mode of being-in-the-world-with-others, from which individual cognition is itself a derived narrative.

Various efforts are underway to harness the opportunities of global networking of information to make course materials from advanced educational centers more broadly available around the world. These include wiring schools for the Internet, distributing networked tablets, offering massive-open-online courses (MOOCs), as well as offering open educational resources (OER), although these initial attempts rarely adopt pedagogies of collaborative learning. A CSCL approach would add support for engaging students in joint inquiry of the available resources, involving intersubjective meaning-making and collaborative knowledge building. This volume stresses the importance of supporting the collaboration in order to make technological innovations truly transformative. Part II concludes with two reports of tentative but systematic attempts to deploy CSCL initiatives at the level of national school systems. They document efforts to develop cultures of collaborative learning in school districts. They are suggestive of an international effort that could prove transformative. As technology transforms and interconnects working, learning, and thinking around the world, it calls for recognition of the importance of collaboration, which currently lags behind. Within the vision of human cognition as increasingly global, the goal of promoting worldwide collaborative learning seems inevitable, if currently challenging.

The selected papers from *ijCSCL* in Part II raise issues of CSCL theory, such as the nature of intersubjectivity, joint attention, shared experience, meaning-making, artifact usage, reference, temporal sequentiality, discourse structure, multiple levels of description, primary unit of analysis, external memory, group practices, and group cognition.

Introducing Part III

These issues are further explored in the VMT research papers in Part III. The Virtual Math Teams (VMT) Project has already been extensively documented in four previously published volumes:

- *Group Cognition: Computer Support for Building Collaborative Knowledge* (Stahl, 2006a). This collection of research reports motivates the design of the VMT Project. It begins with several attempts to design support for collaborative learning and cooperative work. Challenges that arose in these efforts showed a need for deeper theoretic foundations, raising questions concerning the preconditions for productive collaboration. The concept of "group cognition" emerged during the

compilation of this book as a label for the shift of focus in research on learning to the small group as the primary unit of analysis for investigation. It seemed important to begin to collect data systematically documenting student interaction within a paradigmatic CSCL setting. Final chapters report on initial findings from students chatting about mathematics problems. At this stage, the proposals that mathematics could be learned collaboratively; that successful CSCL outcomes could be generated, recorded, and analyzed; or that interaction in such data could be understood in theoretical and practical terms were all hypothesized as questions to be investigated.

- *Studying Virtual Math Teams* (Stahl, 2009) documents the VMT Project as it began to explore technology for supporting student mathematical discourse. Core issues of pedagogy, analysis, and theory are considered in relation to technological features. The VMT system integrated a shared whiteboard with text chat. Sessions were automatically recorded so that student interaction could be replayed and analyzed in detail by researchers. First examples of successful CSCL sessions are presented here, along with analysis of many aspects of the technology, pedagogy, and methodology brought to bear. Presented case studies show that collaborative learning could provide a powerful approach to mathematics instruction.
- *Translating Euclid: Designing a Human-Centered Mathematics* (Stahl, 2013) reflects on the final version of the VMT Project from a dozen perspectives. The co-evolution of theory, methodology, pedagogy, and technology through iterative cycles of design and testing illustrates a design-based research approach. At this point, a multi-user version of GeoGebra was integrated into the shared whiteboard, to allow teams of students to construct and explore strategically selected geometric figures and gradually learn to think/discuss geometrically and solve problems collaboratively. This book confirmed the hypotheses about the possibility of generating, recording, and analyzing successful CSCL sessions of collaborative online learning in the illustrative domain of dynamic geometry.
- *Constructing Dynamic Triangles Together: The Development of Mathematical Group Cognition* (Stahl, 2016) provides a book-length longitudinal study of how a specific group of three young girls began to learn dynamic geometry together. The detailed analysis shows how the group successively adopted a productive set of group practices for collaboration, geometric construction, problem solving, and mathematical discourse. This provides a paradigmatic example of a CSCL approach to teaching a student group a challenging school subject involving practices of rational analysis. It illustrates a method for analyzing longer sequences of interaction that build group competencies—showing how interaction in such data can be understood in theoretical and practical terms as collaborative learning and group cognition.

Part III of the current volume elaborates theoretical issues that were raised in these books. It thereby supplements them and completes the documentation of the VMT research effort.

During several years, the VMT Project conducted Fests, in which students were invited through their teachers to participate in online small-group sessions of mathematical problem solving. This generated most of the data analyzed by researchers. Some sessions were particularly well suited for analysis due to continuity of participants. Key examples of interaction data from these VMT sessions appear in multiple Investigations. The most intensively analyzed sessions were those of the following student teams:

- Teams in the VMT Spring Fest 2005, including the students ImH and Jas as well as Sup, Pin, and Avr [Investigations 22, 23] (see also Çakir, 2009)
- Team B in the VMT Spring Fest 2006, including the students Quicksilver, Bwang, and Aznx [Investigations 5, 8, 16, 19, 25] (see also Medina, 2013)
- Team C in the VMT Spring Fest 2006, including the students Qwertyuiop, 137, and Jason [Investigations 12, 16, 17, 19, 21, 24] (see also Sarmiento-Klapper, 2009; Zhou, 2009)

- The Cereal Team in the VMT Winter Fest 2013, including the students Cheerios, Fruitloops, and Cornflakes [Investigations 9, 16, 18, 22] (see also Stahl, 2013)

The Investigations of Part III draw theoretical consequences from the analysis of interaction in these case studies.

It is not necessary to read the Investigations in this volume in order. The 25 presentations are structured so that they can be skimmed, read, studied, or skipped in any order. Each is self-contained, incorporating its own problematic, argument, literary style, and reference section. Most of the Investigations are reprints or adaptations of earlier publications (see Notes on the Investigations), originally focused on a special point for a particular audience. They retain some of the emphasis deriving from their origin during a particular point in the development of the theory of group cognition.

To aid in integrating the whole presentation, connections and references among the Investigations abound—both implicitly and explicitly. It is hoped that the different presentations support and enhance each other, gradually building a sense of the depth, evolution, and power of group-cognition theory, as well as of the potential of the CSCL field to empower students to tackle the daunting challenges of the future collaboratively.

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Part I

Overview

Investigation 1. Advancing a CSCL Vision

Gerry Stahl

Abstract

The field of computer-supported collaborative learning (CSCL)—as a unity of educational practice and academic research—is characterized in this investigation by a specific vision of learning, illustrated by a prototypical research effort. A number of recent publications are reviewed to extend the scope of CSCL in response to contemporary theory and current social issues. This leads to advancing theoretical concepts and frameworks for conceptualizing CSCL research and practice, which contrast with traditional educational approaches. Although these ideas were originally proposed in disparate contexts, they provide the conceptual skeleton of a unified theory for CSCL, which would be distinguished from popular theories of individual learning and would integrate technological support with collaborative cognition. These insights concerning theory have methodological implications for analyzing CSCL interventions in terms of group knowledge-building practices mediated by interactionally appropriated artifacts. Revised forms of analysis can help innovators evaluate CSCL trials during iterations of design-based research, leading to revisions of the collaborative-learning theory and research methods. Bridging from academic research to educational practice, two examples of efforts to bring the CSCL vision to scale within national school systems are then reviewed. Finally, a global collaboration among CSCL researchers is recommended for effective implementation of the CSCL vision in education worldwide, based on the presented conceptualizations of a unified theory of collaborative learning and their implications for evaluation of CSCL technical and pedagogical designs. This could advance the field of CSCL in its theory and practice, toward its underlying vision of cognition at the group level.

Keywords

CSCL theory · Group practice · Design-based research · Scaling up · Cognitive evolution · Group cognition · Sequential analysis · Knowledge objects · Referential resources · Temporal analysis · Instrumental genesis · Intersubjective meaning making

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Defining a CSCL Vision

Previous attempts to circumscribe the field of CSCL have faltered; the target is so nebulous, controversial, disjointed, multidimensional, and agonistic. Most of these endeavors have tried to specify operational criteria for inclusion of papers in the CSCL corpus (Akkerman et al., 2007; Jeong & Hmelo-Silver, 2016; Jeong, Hmelo-Silver, & Yu, 2014; Kienle & Wessner, 2006; Lonchamp, 2012; Schwarz & Wise, 2017; Tang, Tsai, & Lin, 2014). However, such attempts to apply "objective" standards generally fail to include some of the most important contributions, especially those that are more theoretically oriented. As a multidisciplinary field, CSCL papers bear more of a "family resemblance" (Wittgenstein, 1953) to each other, sharing diverse constellations of characteristics and relationships, rather than fitting a definition with clear and distinct necessary and sufficient conditions (Descartes, 1633/1999).

Perhaps that is why the first definition of CSCL (Koschmann, 1996) presented it as a "paradigm," contrasting it with earlier educational-technology research paradigms like computer-assisted instruction, intelligent tutoring systems, and constructionist exploratory environments—which all focused on learning by individuals, conceived in terms of behaviorist, cognitivist, or constructivist psychology, respectively. However, Koschmann (2001) soon realized that actual CSCL research did not form a neat paradigm, contrasting with earlier, incommensurate research approaches, but included an eclectic mixture of mutually conflicting theories, methods, pedagogies, and settings.

A frequently cited introduction to CSCL (Stahl, Koschmann, & Suthers, 2006) characterizes its approach as "studying how people can learn together with the help of computers." This generic characterization is immediately followed with the warning that CSCL "has a complex relationship to established disciplines, evolves in ways that are hard to pinpoint and includes important contributions that seem incompatible." It suggests that one should "view CSCL as a vision of what may be possible with computers and of what kinds of research should be conducted, rather than as an established body of broadly accepted laboratory and classroom practices."

It seems that what we need is neither a definition of past work nor a paradigm of an ideal science but a focused yet open vision for the future—along with a concrete "prototype" example to serve as a cognitive reference point (Lakoff, 1987). A prototype example is a typical instance that often comes to mind, like a robin is a prototypical bird, although it has various similarities and differences to other birds, like turkeys or penguins. Therefore, I will here sketch a vision of CSCL based on my own efforts to develop a prototypical CSCL design. In addition, I will consider a selection of papers published in *ijCSCL* that I feel have until now been undervalued in setting future directions for CSCL. These papers suggest how to extend existing examples of CSCL research to a growing family of related efforts.

The vision of CSCL advanced here is that students working in small groups can productively incorporate collaborative learning centrally in their schooling and in their intellectual development, taking advantage of appropriate forms of computer support. As CSCL is adopted as a foundational form of learning in educational systems around the world, students will acquire collaborative group practices, individual cognitive skills and technology-enhanced abilities to enable them to address the challenges of contemporary social issues.

Collaborative learning is a primary form of human learning, and facility in collaborating can enhance student participation in other learning. Meanings and practices developed by small groups can result in understandings and skills of the individual group participants—although the correspondence between learning at the different levels is by no means direct or necessary. Increasingly today, with the Internet, students and others can form spontaneous, opportunistic, or long-term networks to discuss, debate, and explore topics of interest—including issues of global importance; students can learn to build knowledge together and refine understanding by sharing perspectives. Formal education

in schools can involve mutually supportive mixes of individual, small-group, classroom, and networked activities. Collaborative learning can be extended outside the classroom as well.

Although knowledge has always been a social product in many senses, the ubiquity of computers and networking tremendously expands the potential to collaborate in building knowledge, to take advantage of computational support for knowledge creation, or to share and preserve knowledge. On the other hand, the proliferation of technology has also contributed to enormous societal problems: climate change, income inequality, overpopulation, fake news, nuclear proliferation, and political schisms. The skills acquired during CSCL sessions in working, problem-solving, conceptualizing, and reflecting together in small groups may be critical for addressing such pressing social issues of our times, as this investigation will suggest.

Two major sources for CSCL theory are Vygotsky (1930/1978) and Lave and Wenger (1991); they proposed influential perspectives on mediated cognition and social practices—i.e., shifting the traditional focus from methodological individualism (including positivism, behaviorism, and cognitivism) to the mind in society mediated by artifacts and the community of practice as the primary level of analysis. Two early investigations following these perspectives and also definitive of the CSCL vision were those of Scardamalia and Bereiter (1996) and Teasley and Roschelle (1993); they extended the unit of analysis to the group or classroom and to the joint problem space as represented by knowledge artifacts and as observable in shared discourse. These initiatives have been conceptually elaborated in subsequent CSCL theoretical papers, as we will see in the following.

My prototypical example of computer-supported collaborative learning involves a team of three 13-year-old girls interacting in the Virtual Math Teams (VMT) online environment to investigate dynamic geometry. The software allows a team of students to explore mathematical tasks in a shared dynamic-geometry workspace, which responds interactively to their actions constructing and dragging points, lines, triangles, and so on. The student discourse takes place through textual chat in the same software environment. Tasks from the teacher and curriculum displayed in the workspace include example constructions, technical terminology, and prompts for collaboration and discussion. The analysis of the team's eight hours of interaction (Stahl, 2016) is carried out at the small-group unit, documenting how the team adopted over 60 "group practices" [Investigation 16] of collaborative interaction, geometry construction, problem-solving, and mathematical discourse. Without speculating about what took place in the individual students' minds, the analysis shows how the team achieved impressive geometry accomplishments as a group and documents that each individual significantly increased her geometry skills through participation in the collaborative learning.

This example prototype is specific in many ways that are typical of some CSCL projects but not others: the team is a small group of students meeting online in an after-school club. It interacts through chat and actions in a multiuser application (see Fig. 1.1). Pedagogical guidance is supplied by a carefully crafted sequence of tasks. Interaction in the group takes place as mediated by reference to the task descriptions, previous chat postings, construction actions, and graphical figures. Analysis tracks the sequentiality of chat and math events as they develop within a network of artifacts, meanings, questions, technical terminology (e.g., "dependency"), and practices (e.g., dragging points to test for geometric dependencies). The subject domain has broad implications for learning: studying Euclidean geometry has served since Plato as the classic gateway to logical thinking and deductive argumentation (Stahl, 2013); collaborative, computer-supported dynamic geometry could similarly serve as a training ground for the group cognition required for democratic responses to contemporary social issues through deeper understanding of interconnections among actors and factors.

Each of this prototype's specifics could be expanded by other CSCL efforts with family resemblances to it. The VMT project illustrates one typical approach to CSCL, but it has differences from other current or future instances. To extend from this example, synchronous text chat can be replaced by asynchronous discussions, perhaps increasing reflection but lessening the flow of thinking together.

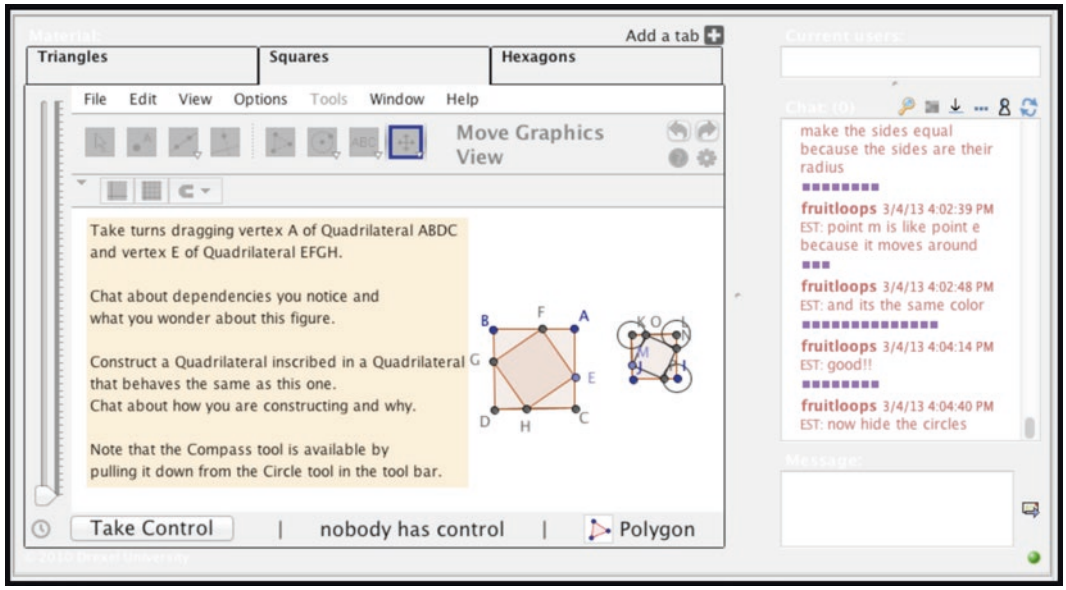

Fig. 1.1 The VMT interface. The team has constructed square IJKL and inscribed another square inside it, based on exploration of the given example of square ABCD and past group experience constructing inscribed triangles

Other knowledge domains can be supported with appropriate tools and curriculum. The role of computers in collaborative knowledge building can switch from communication medium to face-to-face workspace or embodied virtual reality. The after-school math club can grow to international networking, bringing different cultures together. CSCL environments can include scientific models, simulations, or artistic media. They can be supported with feedback and analytics of the interaction for student awareness, teacher overview, and researcher analysis.

The following consideration of several evocative papers in *ijCSCL* suggests possible dimensions for fruitful advances in the scope of CSCL from a focus on the micro-level interaction within small groups of students. This could lead to a growing family of theories, research projects, and institutional interventions resembling each other in various ways and all pursuing the underlying CSCL vision.

We will now review a number of *ijCSCL* papers that are suggestive of directions for progress in CSCL. This will provide an overview and contextualization of the investigations published in part II of this volume. The following comments on these papers are only meant to highlight some themes addressed by the papers and to motivate the careful reading of the investigations themselves.

Extending the CSCL Vision

In the first year of *ijCSCL* publication, Jones, Dirckinck-Holmfeld, and Lindstrom (2006) [Investigation 3] proposed dramatically broadening the concerns of CSCL to include the larger socio-technical context and infrastructure. These authors argue for a relational, indirect, meso-level approach to CSCL design, which would go substantially beyond the traditional paradigm of educational studies. In this approach, the phenomena at the micro level are understood as outcomes of processes of development within their larger contexts.

Most educational research aims at objective results based on a view of the world as having fixed characteristics: it is assumed that technologies have inherent affordances, individual utterances have

definite intended meanings, subjects have rational thoughts (logically connected mental representations), and analysis can be carried out algorithmically. Investigation in this tradition is conducted at the individual unit of analysis, classifying student utterances as expressions of imputed intentions of individual speakers.

The paper by Jones, Dirckinck-Holmfeld, and Lindstrom takes a very different tack. It proposes that affordances of CSCL technologies should be understood in terms of how they are taken up by users in the interactions that the technologies mediate. Meaning is here seen as an intersubjective product of the interaction among multiple people within their conversational context, including its technological artifacts and infrastructure. The concern is with the unfolding process of (group) meaning making within these settings, rather than in traditionally conceived (individual) learning outcomes.

Analysis in this approach is complex, viewing each aspect of task, technology, personality, role, utterance, response, or knowledge as interrelated or relational. Data is not directly determinant but negotiated by participants and necessarily interpreted by researchers who understand colloquial language and human interaction. Furthermore, analysis of CSCL interactions is understood on many interpenetrating levels: the micro level of individual utterances and brief interactions, the small-group level of interacting teams of learners, the classroom level of teacher-led instruction, the local-culture level of schooling, and the global level of geopolitical and historical influences. Such multifaceted analysis requires computer-supported collaboration among the multidisciplinary researchers themselves; it is notable that Investigation 3 was written by authors from three different countries.

The meso level of the community points to the realm of social practice as the locus within which interactional processes are situated; the social practices are taken up in small-group activity. This focus corresponds to the "practice turn" in contemporary social theory (Schatzki, Knorr Cetina, & Savigny, 2001). In a practice-oriented analysis, structures are emergent; they grow out of recursive interactions among people, technologies, and social action. In this post-cognitivist view [Investigation 15], it is not mental representations in individual minds or designed properties of technology that directly structure the practice. Rather, it is through a recurrent and situated practice over time—a process of enactment of a relevant practice by a group—that people constitute and reconstitute a structure of technology use.

CSCL designers have only limited direct control over how their designs are actually used by students. How learners respond to, understand, and enact artifacts in relation to any educational design is a complex structuration process that has to be studied in practice. Investigation 3's authors contend that the CSCL tradition has pursued a relatively narrow focus that places in the background issues concerning the politics, policies, institutions, and infrastructures in which the processes of CSCL take place. They argue for a greater inclusion of what they call the meso level of collaborative learning, as opposed to the trend toward networked individualism—the conception of collaborative groups in terms of their individual members. They asked—already back in 2006—whether CSCL, and education more generally perhaps, should act as a critical opponent to some of the trends identified in the networked society and stand up against networked individualism.

Several books published in recent months highlight the acute and growing importance for the survival of modern society of issues at the technological meso level or the knowledge infrastructure. Collaborative learning could prepare students to address such issues in the future, if CSCL develops effective appropriate interventions. The social issues have arisen in part as a result of the prevalence of individualism: understanding things from the epistemological perspective of a rational individual mind seeking its own personal benefit, rather than seeing how things are increasingly interrelated and interdependent. By bringing multiple personal perspectives together to analyze dependencies in studied phenomena, collaborative learning provides both an approach and a model that transcend the individualistic in favor of the collective or collaborative.