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Group practices: a new way of viewing CSCL

Gerry Stahl[1]

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Q1 **Abstract** The analysis of *group practices* can make visible the work of novices learning how to inquire in science or mathematics. These ubiquitous practices are invisibly taken for granted by adults, but can be observed and rigorously studied in adequate traces of online collaborative learning. Such an approach contrasts with traditional pre/post comparisons that miss sequential interactional processes or that reduce group phenomena to individual or social factors. The analysis of the enactment of practices by small groups in CSCL contexts can systematically inform the design, testing, and refinement of collaborative-learning software, curriculum, pedagogy, and theory. CSCL can be re-conceptualized as the design of technology to foster the adoption of group practices by student teams.

Keywords Group practices · CSCL theory · CSCL methodology · Design-based research

A "squib" is a brief statement, intended to ignite thinking and discourse on topics of theoretical importance. Here, I summarize a conclusion about CSCL theory that emerged from writing about the research I directed from 1991 to 2015. While the most penetrating theoretical insights develop through writing books, it is not practical to expect readers to pour through the detailed analyses available at http://gerrystahl.net/elibrary. Hence, this squib, which for the first time explicitly describes a new way of viewing CSCL that surfaced in this research.

A new method for CSCL

As a CSCL researcher, participant in all previous CSCL conferences, and former Editor of *ijCSCL*, I have consistently observed that most published studies of collaborative learning reduce it either to individual mental representations or to cultural social practices; the small-group unit of analysis is under-researched (Stahl 2006a). This may be partially because it is difficult to find data that adequately documents collaborative learning by reliably capturing all

Gerry Stahl
Gerry@GerryStahl.net

[1] Drexel University, Chatham, MA, USA

the discourse, gestures, and artifacts that enter into *group* (i.e., collaborative) knowledge-building processes (Stahl 2013a). Furthermore, the methods of traditional educational-psychology research are inadequate for investigating many core CSCL issues because they focus on individual cognition and assume that utterances can be categorized objectively (i.e., without interpretation based on understanding the sequential meaning-making) (Stahl 2014). My conclusions are controversial within the CSCL research community because they methodologically eschew prevalent cognitivist and positivist assumptions (associated with methodological individualism) (Stahl 2016c).

Throughout the history of CSCL as a research community, the methodological tension of the field has been informally described as an opposition of "quantitative" versus "qualitative" approaches (Jeong et al. 2014; Suthers et al. 2010). Habermas refined this with the epistemological distinction between calculative and sense-making orientations, which pervades modern science (Hammond 2015). Sfard (1998) saw the contrast as (individual) acquisition versus (cultural) participation. Viewed in terms of the unit of analysis, "socio-cognitive" psychology focuses on representations in individual minds and "socio-cultural" anthropology centers on socially defined practices—there has been no methodological focus on the small-group unit of analysis, where one would expect to observe collaborative learning in CSCL (as in Stahl 2009). Some psychologists recognize that individual learning can be influenced by groups (Cress 2008), and some sociologists show how social practices are enacted and maintained in group interaction (Garfinkel 1967; Giddens 1984). However, as noted by Schwarz and Baker (2017), even these studies rarely analyze empirical data of collaborative learning in ways that display processes of small groups building knowledge or acquiring practices.

Quantitative and qualitative methods are appropriate for measuring net changes due to hypothesized independent variables. However, CSCL needs ways to analyze the group processes that bring about such changes and that establish group practices—in order to guide iterative design-based research (DBR). To not only judge the statistical effectiveness of CSCL interventions in promoting collaborative learning, but also to identify specific problems and to suggest innovative functionality during DBR cycles, it is necessary to analyze temporal group processes, such as the adoption and use of group practices, in their sequential unfolding (Stahl 2013b).

Traditional methods provide evidence *that* change has taken place, without describing *how* the change took place, beyond speculation based on assumptions from folk theories of cognition (Stahl 2016c). For instance, groundbreaking CSCL studies (Kapur and Kinzer 2009; Scardamalia and Bereiter 2014; Schwartz 1995) indicated that important learning took place at the group level, without being able to show how it happened. A number of researchers have proposed that unique cognitive processes take place at the small-group level (e.g., Barron 2003; Dillenbourg et al. 1996; Hutchins 1996; Rogoff 1995), but they have not collected the required data for a systematic analysis at the group unit.

Sfard (2008) argued that learning math is a matter of acquiring many *practices* that are passed down in the culture of mathematics. Vygotsky laid the basis for collaborative-learning theory by proclaiming that practices are acquired socially (e.g., in dyads or small groups) first and subsequently adopted by individuals. This notion of practices—when applied at the group unit of analysis—provides a way of conceptualizing regularities of group cognitive processes. My colleagues and I set out to generate and analyze CSCL interactions in which we could empirically observe such small-group practices emerging.

Studies of group practices

In 2002, we initiated the Virtual Math Teams (VMT) research project at the Math Forum. We gradually developed a prototypical CSCL DBR project, which investigated mathematical education with small teams of students in a custom online collaboration environment. The VMT software was instrumented to collect comprehensive interaction data and to provide it to researchers in useful formats. Later, we developed and incorporated a multi-user version of GeoGebra to provide computer support more specifically for dynamic-geometry math content.

My published books draw successive lessons from the phases of this research: *Group Cognition* (Stahl 2006a) proposes analyzing knowledge-building phenomenon at the small-group unit of analysis. *Studying VMT* (Stahl 2009) describes our scientific approaches to supporting and analyzing small-group problem solving in the VMT context. *Translating Euclid* (Stahl 2013b) discusses the many facets of DBR for supporting constructionist CSCL using VMT.

Finally, *Constructing Dynamic Triangles Together* (Stahl 2016a) follows utterance-by-utterance a team of students developing mathematical understanding through an eight-hour longitudinal case study, as the group progressively masters collaborative online dynamic geometry. It identifies about sixty "group practices" that the team explicitly, observably enacts. We found that these practices successively contribute to various core aspects of the group's abilities: to collaborate online; to drag, construct, and transform dynamic-geometry figures; to use GeoGebra tools; to identify and construct geometric dependencies; and to engage in mathematical discourse about their accomplishments.

The notion of *group practices*, as it emerged in this research, provides a foundation for a new way of viewing, analyzing, theorizing, and supporting CSCL. Group practices mediate between individual cognition and community culture (Stahl 2006a, p. 16; Stahl 2013b, Chapter 8). They can be observed and analyzed in small-group interactions. Thereby, the theory of group practice provides a research-based solution to the obstinate issues of meaning making, intersubjectivity, structuration, and connecting levels of learning (Giddens 1984; Stahl 2012b, 2016a), while focusing analysis on the small-group unit as central to collaborative learning. Intersubjective meaning making and knowledge sharing take place via group practices like turn taking, pointing, questioning and drawing. Individuals can transform the group practices into personal skills and mental abilities. Practices can also pass back and forth between small-group and classroom or cultural levels.

The group practices identified in VMT studies are all based on captured interaction data. These practices arose in observable breakdowns or interactional difficulties and were each enacted explicitly in student discourse. Ethnomethodologically speaking, the practices are observably issues for the participants themselves (Stahl 2012a). They can be identified through close analysis of discourse and other forms of interaction, such as geometric sketching or pointing within the online VMT environment.

The identification of group practices has substantial implications for the design of CSCL software, curriculum, pedagogy, and experimental interventions. In DBR, one develops an initial prototype environment and tries it out with groups of students. Based on observation of problems, the prototype is iteratively re-designed and refined. By observing breakdowns in group interaction and the gradual enactment of new group practices in response to the breakdowns, a designer can identify problem areas and constructive processes that need additional support. The analysis of group practices provides a systematic analysis method for driving CSCL design—something that has long been lacking in CSCL (T. Koschmann, M. Scardamalia, personal communications).

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Theory of group practices

Our focus on *group practices* as foundational to collaborative learning is in keeping with the "practice turn" in contemporary social theory and epistemology (Schatzki et al. 2001). According to Reckwitz (2002), a practice is "a routinized type of behavior which consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, 'things', and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge" (p. 249). Social practices form our background, tacit knowledge as proposed by twenty-first-century philosophy (see Stahl 2016c) as an alternative to eighteenth-century rationalist (Descartes 1633/1999) and cognitivist (Kant 1787/1999) philosophies.

Practice theory was propounded by Bourdieu (1972/1995). He uses the term "habitus" for our systems of durable, transposable dispositions—or organization of conventionalized, routinized, objectified, and embodied habits. As with other concepts, I construe practices primarily at the small-group unit of analysis, rather than as habits of individual bodies or cultural conventions of whole communities—in contrast to Bourdieu and his followers. Group practices are what make collaboration possible: "The homogeneity of habitus is what—within the limits of the group of agents possessing the schemes (of production and interpretation) implied in their production—causes practices and works to be immediately intelligible and foreseeable, and hence taken for granted" (Bourdieu 1972/1995, p. 80).

Only because group members share the ability to use the same group practices, can the members understand each other's actions and their references to those actions. The intersubjectivity of the group is based on this shared meaning (Stahl 2016b). The sharing of meaning is a product of the group interaction that adopts the practice: it is produced in the interaction as the members construct the meaning together (Stahl 2015). Group practices are proposed—whether verbally or in action—and then discussed, negotiated, accepted, put into regularized practice, generalized across instances of practice, and incorporated into the group's habitus. Then we may say that the group—and often its members—has learned. The analysis of group practices provides a vital key to theorizing, supporting, analyzing, and facilitating computer-supported collaborative learning.

Collaborative learning certainly also involves individual cognition and socio-cultural influences. Resources from the individual and cultural levels are necessarily introduced into the group interaction, made sense of, negotiated, shared, and adopted through small-group processes. The adoption of group practices *mediates* the multiple levels involved in learning (Stahl 2013a, b). The analysis of group practices provides a powerful new method to study CSCL. By automatically capturing the complete interaction within inquiring online groups of students, CSCL research has the potential to observe and analyze the subtle development and use of group practices for the first time.

Enacting group practices

In analyses of VMT interactions, group practices largely account for the group's teamwork and for its ability to construct knowledge or problem solve as a group. The enacting of cultural or community practices as their own group practices—facilitated by teachers, texts, scripts, interactional resources, and knowledge artifacts—is how small groups acquire skills from their social context and how the group participants exchange and appropriate each other's perspectives and skills as individual learning (Stahl 2013b, ch. 8). The answer to the question of how the group learns is that it successively adopts various practices and incorporates them in its on-going interaction. As Vygotsky (1930/1978) proposed, such small-group learning generally precedes learning by "isolated individuals" (still surrounded by texts, motivations, and objectives from family members, workplace colleagues, classroom friends, and other small groups).

As observed in our studies, the adoption process often follows a general pattern (Stahl 2016a):

- First, the group encounters a "breakdown" situation in which they do not know what to do.
- Then someone makes a proposal for action. There may have been a preceding series of proposals, some ignored or failed (see Stahl 2006a, Chapter 21) and others rejected by the group.
- The proposal may be followed by a negotiation process as group members question, refine, or amend the original proposal through secondary proposals.
- Finally, there is often an explicit round of agreement.
- Perhaps most importantly, the new practice is put to work in overcoming the breakdown situation.
- In the future, the practice may be simply applied without discussion. Of course, there could also be instances of backsliding, in which the group fails to apply a previously adopted practice where it could help.

This general pattern is not a rational model of mental decision-making. Rather, it involves tacit behavior, where a breakdown leads to explicit knowledge, followed by negotiation and eventually a return to tacit practices (Stahl 1993, Chapter 4). The adoption process is driven by interpersonal interaction engaged in the world, not by logical deductions in individual minds.

The catalog of group practices compiled from analysis of VMT data agrees well with lists of social practices enumerated in the literature (Stahl 2016a). For instance, we identified online analogues of group practices ("member methods") defined by face-to-face Conversation Analysis: sequential organization (response structure), turn taking, repair, opening and closing topics, indexicality, deixis, linguistic reference, and recipient design (Zemel et al. 2009). Other group practices correspond to practices CSCL has previously investigated: joint problem spaces, shared understanding, persistent co-attention, representational practices, longer sequences, and questioning (Stahl et al. 2011). Within both our work and other CSCL reports, practices in mathematics education include: mathematical discourse and technical terminology; pivotal moments in problem solving; and the integration of visual/graphical reasoning, numeric/symbolic expression, and deductive narrative (Cakir et al. 2009).

The idea of centering CSCL analysis on group practices emerged from study of VMT data. Publications that present that data discuss the theory, methodology, and implications of the focus on group practices extensively. To ground this squib in that data, we point to four case studies that analyze group practices:

Study 1: A group practice of referencing

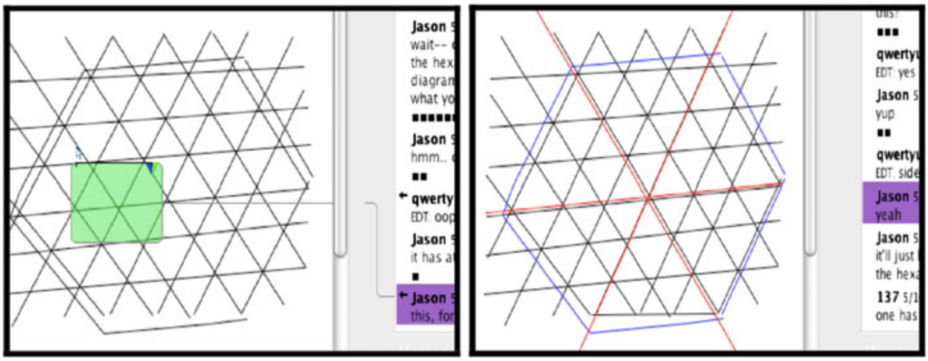
Pointing, referencing, or deixis forms a ubiquitous class of gestures essential for maintaining collaboration, including online (Stahl 2006b). In Log 1 from Team C in the VMT

SpringFest 2006, three students use a whiteboard integrated with VMT's chat tool to explore arrays of hexagons. In Line 709, Jason halts discussion until he can "see" what student 137 has proposed. Qwertyuiop has drawn an array of lines to check his understanding of 137's post (Fig. 1). As analyzed in (Stahl 2013b, Section 8.1), this leads to work by the group to establish practices for making focal geometric figures visible to each other by coloring lines that outline or divide up the figures.

Line	Time	Student	Chat post
705	19:15:08	137	So do you want to first calculate the number of triangles in a hexagonal array?
706	19:15:45	qwertyuiop	What's the shape of the array? a hexagon?
707	19:16:02	137	Ya.
708	19:16:15	qwertyuiop	ok...
709	19:16:41	Jason	wait-- can someone highlight the hexagonal array on the diagram? i don't really see what you mean...
710	19:17:30	Jason	hmm. Okay
711	19:17:43	qwertyuiop	oops
712	19:17:44	Jason	so it has at least 6 triangles?
713	19:17:58	Jason	in this, for instance
714	19:18:53	137	How do you color lines?
715	19:19:06	Jason	there's a little paintbrush icon up at the top
716	19:19:12	Jason	it's the fifth one from the right
717	19:19:20	137	Thanks.
718	19:19:21	Jason	there ya go: -)
719	19:19:48	137	Er... That hexagon.

Log 1.

In the minute from his interruption of the mathematical talk at Line 709 to his resumption in Line 713, Jason demonstrates that he sees the hexagon that has been outlined by 137 in black lines (Fig. 1, left), by making a new mathematical proposal and pointing from his chat posting to a small hexagon using the VMT pointing tool. Soon thereafter, the group divides the larger hexagon into six triangles using a practice involving colored lines (Fig. 1, right). We also see the sharing of tool-use practices as Jason guides 137 in coloring lines in the VMT whiteboard, after which 137 colors his outline blue. Later, the group makes more complicated relationships within the array easily visible with colored lines, allowing the group to derive formulas working collaboratively step-by-step.



Q2 **Fig. 1**

Study 2: Group practices over time and across individuals

In a longitudinal analysis of another VMT team—Team B in SpringFest 2006—Medina et al. (2009) identify several group practices and show how they are enacted and repeatedly used across all four of their VMT sessions (see Fig. 2).

In each session, a different participant initiates interaction by first producing a whiteboard drawing that the other two subsequently orient to through chat. In their Sessions 2 and 3, the practice of *inscribe-first-solve-second* is iteratively enacted and composed with two additional practices—*modulate-perspective* and *visualize-decomposition*. In Session 2, Quicksilver's use of color and perspective emerges in the joint work in support of both representational and problem-solving practices. In Session 3, Bwang appropriates color to draw out the particular decomposition previously articulated by Aznx. This demonstrates both shared understanding and individual adoption of the shared group practices.

Study 3: A group practice supporting collaboration

It is particularly informative to observe novices confronting a completely new challenge. In the start of WinterFest 2013, teams of middle-school students faced VMT's multi-faceted software interface and a new form of mathematics, dynamic geometry. Here is the opening interaction of a group of three fourteen-year-old girls we call the Cereal Team (Fig. 3; Log 2), analyzed in (Stahl 2016a, Session 1).

Line	Time	User	Message
3	13:39.4	Cornflakes	Hey
4	13:57.0	Fruitloops	Hello
6	14:19.1	Cheerios	Hey
7	14:45.6	Cheerios	Whose froot loops
8	14:53.9	Cornflakes	xxxxxxxx [name removed from log for privacy]
9	15:10.8	Cheerios	Whose takimg control
10	15:20.1	Cheerios	Taking*
...			
21	16:18.4	Cheerios	So whoses doing what
22	16:44.4	Fruitloops	Who wants to take control?
23	17:30.6	Cheerios	xxxxxxxx do you want to [name removed for privacy]
24	17:52.2	Fruitloops	No... cornflakes you take controll.....
25	18:01.7	Fruitloops	Who wants to do what steps?
26	18:02.9	Cheerios	Cornflakes take control
27	18:03.6	Cornflakes	No cheerios you can
28	18:14.6	Cheerios	Cornflakes
29	18:25.4	Fruitloops	Cornflakes
30	18:33.6	Cornflakes	NO
31	18:40.0	Cheerios	Why not
32	18:52.3	Fruitloops	I just took control. Lets takes turns
33	19:01.9	Cheerios	Alright
34	19:03.0	Cornflakes	Ok

Log 2.

Note that the group carries over practices of greeting and correcting typos from talking and texting to VMT. However, the group has no idea how to start computer-supported collaboration by taking control of the software and responding to the instructions. Each student

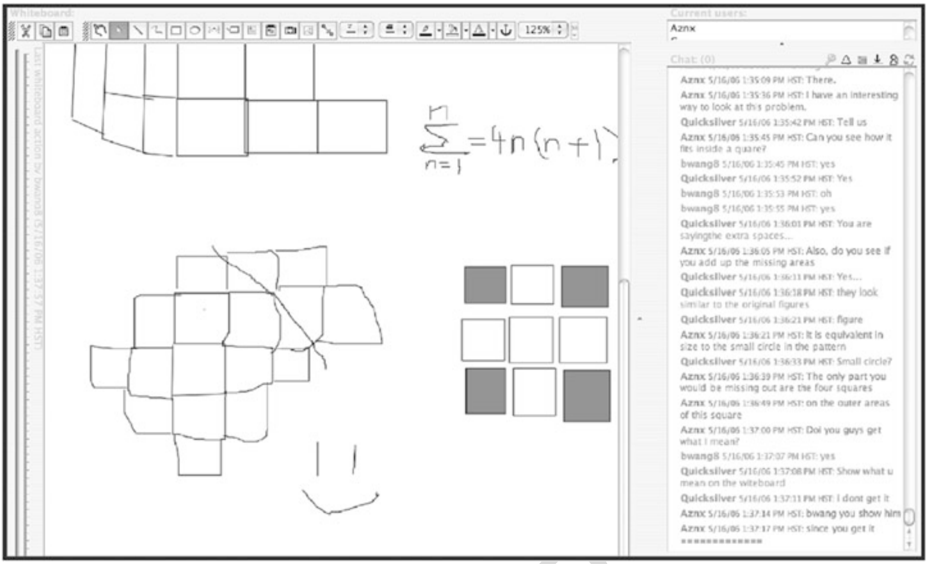


Fig. 2

strenuously resists leading the online group work. Finally, Fruitloops suggests, “Lets take turns” (Line 32). Although suggested in the instructions, this has to be stated explicitly and agreed upon by all to become an effective group practice; thereafter, each session begins by a student taking her turn, and the group work proceeds smoothly.

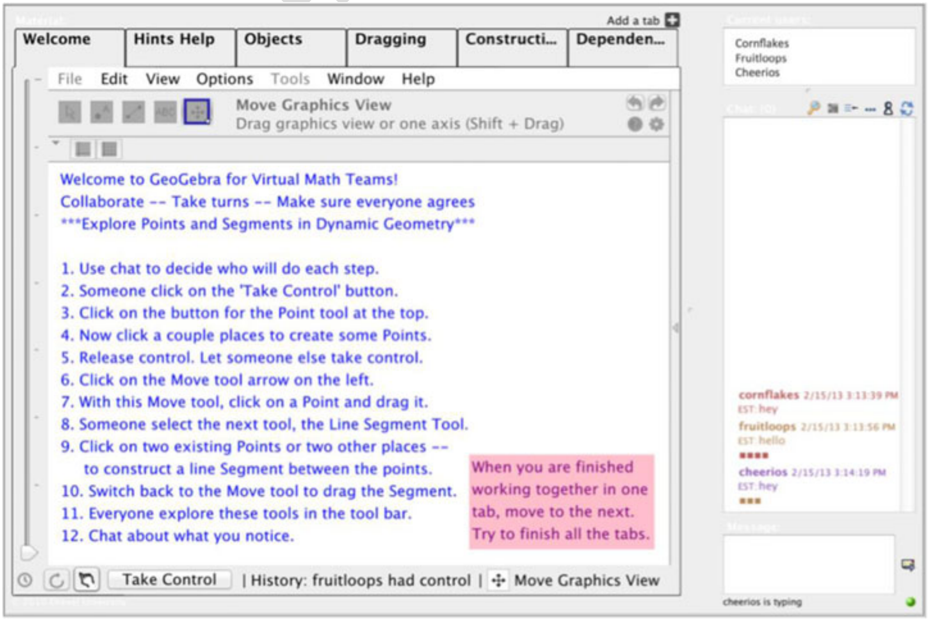


Fig. 3

Study 4: A group practice of mathematical problem solving

We analyzed the Cereal Team's adoption of many group practices during their eight hour-long sessions. One of their most impressive mathematical accomplishments is analyzed in (Stahl 2016a, Session 6). The group explores a given dynamic figure of one square inscribed in another, and then constructs its own figure with the same geometric dependencies (Fig. 4).

This accomplishment and the group's discourse about it demonstrate the team's effective adoption of many mathematical, tool-usage, and collaboration group practices. In particular, they make visible how well the team members each learned the practices enacted in previous sessions (Log 3, esp. Line 146).

135	39:20.3	Cornflakes	Olets start by cinstructing a regular square
136	39:48.0	Fruitloops	I think we should make perpendicular lines somehow
137	39:58.8	Cheerios	Use the perpindicular line tool
138	43:21.9	Fruitloops	The first line segment would be like ab
139	43:27.7	Cornflakes	Yes
142	51:24.7	Cheerios	How do u know ji is straight
143	55:40.6	Fruitloops	I dont know what to do because the points arent the same color
144	56:38.2	Fruitloops	Now after you make the perpendicular lines try to make the circles\
145	57:48.7	Fruitloops	I think you need to know use the polygon tool and make the square
146	59:10.6	Fruitloops	Now we need to use the compass tool lilke we did in the triangles tab
147	59:57.5	Fruitloops	Because af is equal to ec and dh and bc
148	00:42.4	Cheerios	I made a line segment which was if than i used the perpendicular line tool and made 2 lines on each side then used the compass tool and clicked on each point and then the center vertex was i and then made a another circle except the center vertex is j and connected all the points

Log 3.

The analysis of this excerpt requires observing the shared geometric manipulations, noting the reuse of previously acquired group practices and carefully studying the text chat. The data for this is comprehensively preserved by the VMT system.

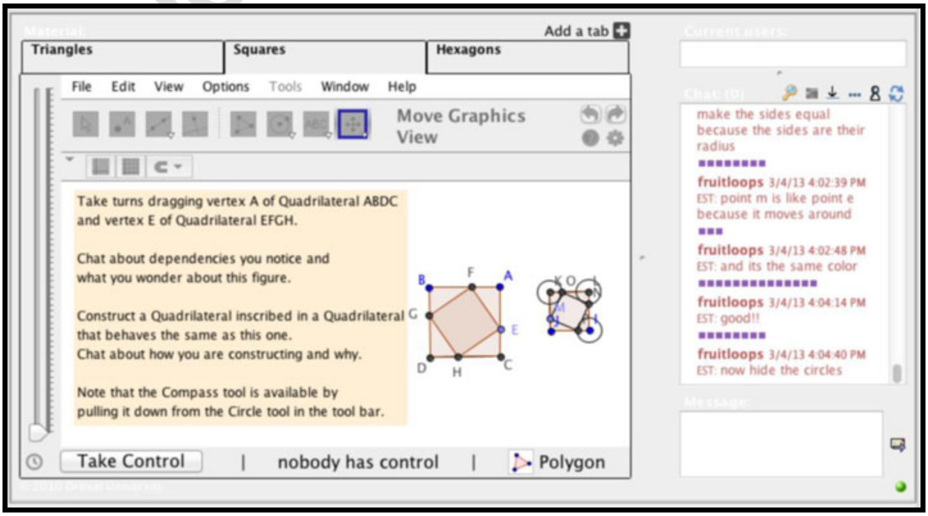


Fig. 4

Designing for group practices

Study 1 shows the importance of pointing practices for establishing common ground. The software provide tools for pointing from a chat posting to a region in the drawing area, for drawing lines around a region, and for coloring lines to highlight a region. The students use these to focus each other's visual attention on a referenced region. In an online environment, creating shared focus is a precondition of productive discourse. In the study's data, we can see how students discover the reference tools and how they inform other group members about them, adopting group practices of using these tools. If other groups failed to find these tools when they were needed or failed to use them appropriately, this could suggest to technology and pedagogy designers to make these tools more visible and to guide students to find and use these tools. Analysis of the group practices in this study suggests retaining the reference tools in future versions and designing more activities that explore and exploit them.

Analysis of group practices in *Study 2* contributes to the theory of CSCL, group cognition, and group practice. For instance, it shows how abilities of one student become shared group practices and how these then become abilities of the other students. Each member of the group in this study contributes a practice that may have been an individual skill or may have been brought in from the larger socio-cultural context. These become shared group practices, which then interact with other group practices, leading to innovations in collaborative mathematical cognition. Analysis focused on the creation, adoption, and application of group practices can provide detailed views of computer support, collaborative knowledge building, and the interplay of processes at different levels of description.

Study 3 is informative because it practically shows the creation of collaboration practices *tabula rasa*. Of course, the students are already teens with developed communication skills, but they are very reluctant to work together in the VMT environment (although they start to explore it and work in it as individuals). The first thing that the screen of instructions (their script) says is, "Collaborate – take turns – make sure everyone agrees." Eventually the group adopts this advice and uses turn taking as a visible group practice. The students talk about whose turn it is and who will take the next turn. However, the group has to go through an adoption sequence before it can enact this group practice to overcome its breakdown in action. The design of the wording of the instructions resulted from the observation of previous studies, which indicated the need for group turn-taking practices. Designers can now debate whether the instructions need further revision based on Study 3 and parallel studies with the same or re-worded instructions.

Study 4 is taken from another session by the team in Study 3, but now (five sessions later), they are already achieving a geometry accomplishment that is challenging for most college-educated adults. The chat excerpt reflects both geometry-construction actions and mathematical reflections by the team. An analysis of the group practices here reveals the importance of the compass tool (technology), of creating equal-length line segments (mathematics), and of explaining what one does so everyone can agree (collaboration). The group is successful because the technology, instructions, and successive activities had been carefully designed to scaffold the adoption of the necessary group practices, based upon previous iterations of VMT testing.

Through analysis of the enactment of group practices while engaging in collaborative dynamic geometry, we determined that a central practice of dynamic geometry is the construction of dependencies. A *dependency* is a constraint on geometric objects that ensures invariance. For instance, in the exemplary Euclidean construction of an equilateral triangle, the sides of the triangle are constrained to be dependent on the radii of circles with equal radii, ensuring that the three sides of the triangle are of equal length to each other. In dynamic geometry, one can drag a vertex of a triangle to make the triangle a different size or orientation; however, if the triangle has been constructed with the correct dependencies, the three sides will stay equal to each other, all getting longer or shorter together.

Geometric dependency is a very abstract notion, challenging for middle-school students to master, as can be seen in the extended analysis of the Cereal Team's group practices (Stahl 2016a, b, c). For instance, Öner (2016) specifically traces the team's struggle in their third session to move from a naïve view of geometry in terms of visual appearances to one of underlying constructed dependencies. Understanding the notion of dependencies in dynamic geometry can be operationalized in terms of identifying specific group practices of construction and discourse. This can then guide analysis and design.

To learn more about effectively scaffolding group practices related to constructing and discussing dependencies, we designed activities and analyzed interaction data from trials. Our final curriculum (technology, teacher training, embedded instructions, geometry challenges, etc.) is all oriented toward fostering and supporting group practices of constructing dependencies and of discussing dependency. While aligned with Common Core introductory-geometry curriculum, the sequence of activities is designed to foster the successive adoption of group practices that build on each other to facilitate increasingly advanced collaboration, mathematics, and argumentation. As designers, we configure activities to be used in ways we intend. However, we need to study how student teams structure their group practices in our designed environment to know how they enact our artifacts. What counts in CSCL is the actual student interaction—structured by group practices—which is always quite different from what the designers envisioned.

Just as we can see in Study 3 the team's difficulty in taking collaborative action before it has adopted the turn-taking group practice, we can repeatedly observe breakdowns in action in later sessions. Especially during periods of geometric construction, the Cereal team seems to flounder excessively. These are indications that additional group practices should be scaffolded and encouraged. For instance, there are many small tricks to doing constructions in dynamic geometry, and these could be introduced more explicitly for adoption as group practices. In addition, students tend to avoid discussing in chat what they are doing in the construction area. It might, for instance, be helpful to model effective geometric-construction techniques and collaborative-discussion patterns in classroom periods before small-group sessions, depending on the educational context. These are new design decisions to be made now, based on analysis of recent interaction data suggesting which possible group practices are important to support.

Analyzing group practices

Group practices are often derived from social practices (of the classroom, school mathematics, culture, etc.), but must be enacted or adopted and used repeatedly by the group to become effective. Groups do this in different, unpredictable ways as a result of their massively over-determined interactions. Every instance of collaborative learning is unique—it cannot be replicated or generalized. However, within a domain like collaborative online dynamic geometry, certain group practices typically recur regularly. Group practices can constitute central structural elements of group knowledge-building interactions. They structure the interaction. They also structure the domain—as practices related to dependency structure dynamic geometry. The cataloguing of group practices identified in the analysis of a corpus of interaction data from CSCL interventions can contribute to research that is directly applicable to CSCL design to support team interactions in target domains.

Traditional experimental methods aim to contribute incremental additions to a body of scientific findings. However, they tend to be summative evaluations that judge the adequacy of supposedly well-defined situations, rather than formative explorations of situations under development and evolution. Summative evaluation is appropriate for studying unchanging natural phenomena. However, CSCL is a design science involving complex human interaction within social contexts in flux. We do not assume that the current design of technology, crafting of pedagogy, preparation of students, or orchestration of collaboration are finalized and perfect—ready for summative evaluation. Rather, we are interested in discovering whether we are making progress along those intermingling dimensions and how we should tweak things for our next design iteration.

In an insightful and comprehensive new review of theory and research in the domain of argumentation in education, Schwarz and Baker (2017) summarize the results of published studies on a variety of aspects of their topic. Invariably, they have to conclude that "more research on argumentation in diverse learning contexts" is needed in each aspect (p. 239). The research they are reviewing consists primarily of attempts to contribute incremental additions correlating variables and effects. What would this even mean in a field where the technology, education theory, and socio-cultural context are fluid and successive studies cannot really be comparable? Furthermore, the point in DBR research is not to evaluate the effectiveness of collaborative learning under current conditions, but to discover avenues to pursue in re-design of our tools, scripts, and theories.

For a DBR science, case studies are generally more appropriate than summative evaluations (Yin 2009). That does not mean that quantitative pre-post studies cannot be helpful in generating or checking hypotheses and suggesting phenomena to look for in detailed interaction analysis. In the VMT project, we often used quantitative and qualitative methods to pursue specific questions. However, we found that the deepest theoretical insights and the best design suggestions derived from detailed interaction analysis of interesting case studies. The examination of group practices can provide a methodological focus for such investigations in the CSCL research context.

Group practices in CSCL

The four case studies excerpted above illustrate the adoption and use of group practices for communicating (pointing), problem solving (problem decomposition), collaborating (turn taking), software usage (compass tool, perpendicular line tool), and geometric construction (of perpendiculars, squares, equal-length lines). By studying the group interactions involved in these practices, we can see in detail just what practices are needed for collaborative mathematics, how groups adopt them, and how well they are supported in our successive prototypes. This is much more useful information for CSCL theory and DBR design than just confirming that groups get a certain result more frequently under certain broad conditions.

A methodological focus on group practices can suggest the design of technologies, curriculum, and pedagogy to support the adoption of key group skills. The analysis of the adoption and reuse of group practices in interaction data can pinpoint how concrete groups learn and achieve (or fail to achieve) group-cognitive accomplishments. The scaffolding of suggested group practices through teacher presentations before group sessions, help videos during sessions, and classroom reflections after sessions can guide and enrich the collaborative-learning experience.

Perhaps CSCL should be viewed as the design, analysis, and orchestration of technology, curriculum, and pedagogy to foster the adoption of productive group practices by student teams.

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