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## Contributions to a Theoretical Framework

*This chapter opens with my Introduction to the proceedings of the CSCL 2002 conference held in Boulder, Colorado, in January 2002. This introduction was intended to set a tone for the conference's emphasis on theories of collaboration.*

*The remainder of this chapter formed my paper at that conference. It argues that looking at computer support for collaborative learning in terms of:*

- a) collaborative knowledge building,*
- b) group and personal perspectives,*
- c) mediation by artifacts and*
- d) micro-analysis of conversation*

*provides a rich, multi-dimensional starting point for conceptualizing and studying CSCL.*

*Each of these ideas occupies an important place in CSCL research. (a) The notion of collaborative knowledge building defines a useful paradigm for conceptualizing learning as social practice. (b) The social interactions and knowledge management activities in which shared knowledge is constructed can be analyzed as the result of interweaving group and personal conversational perspectives. (c) In general, collaborative interaction is mediated by artifacts: sometimes only by transitory artifacts like spoken words or gestures, but increasingly by physical or digital artifacts and media. (d) Empirical studies of collaborative knowledge building employing micro-ethnographic analysis of speech, gesture, artifacts and media can make the details of these collaborative interactions visible, highlighting the interplay of perspectives and artifacts in the trans-personal construction of knowledge. The empirical methodology can overcome the reductionism that was criticized in the previous chapter; this will be illustrated in the remaining chapters of part II.*

*A theoretical framework incorporating models of knowledge building, perspectives and artifacts—and grounded in empirical analysis of collaborative interaction—can guide the design of computer-based artifacts and media as a support for collaborative learning with appropriate, elaborated and unified conceptualizations. This will be expanded upon in part III.*

## Introduction: Foundations for a CSCL Community

### A New Era of Learning

Learning takes place in communities, facilitated by artifacts, which in turn sustain the communities that generate them. A series of CSCL conferences—archived in proceedings artifacts like this one—have been foundational events for a growing CSCL community that has an important role to play in a rapidly and painfully self-transforming global culture.

The CSCL community addresses complex and urgent social issues associated with learning in the information era. Despite its healthy growth curve, this research community is still searching for its foundations; to date, there is little consensus on theory, pedagogy, technology or methodology—even less in the broader world of learning stakeholders.

Learning has become a central force of production. Traditional theories and institutions that rose to meet the needs of reproducing knowledge in an industrial world have become fetters on progress: the focus on individual learners obscures the group as the locus of knowledge building and ignores the global interdependence of learning. Fixation on facts distorts the nature of problem-solving inquiry. Modes of thought deriving from the age of rationality and machinery fail to grasp the subtlety of interaction in hyper-networked environments.

CSCL instinctively aims beyond yesterday's concepts. *Collaborative Learning* does not just mean that individual learning is enhanced by participation in small groups; it means that it is the groups themselves that learn. Knowledge is a product of the collaboration process: it arises through interaction of different perspectives, heats up in the cauldron of public discourse, is gradually refined through negotiation, and is codified and preserved in cultural or scientific artifacts. Knowledge is not static and other-worldly: it lives, situated—both locally and historically—in groups, teams, organizations, tribes, social networks and cultural flash points.

*Computer Support* does not just mean automating the delivery and testing of facts; it means supporting forms of collaboration and knowledge building that can not take place without networked communication media and software tools for developing group understandings. Computers can manage the complexity of many-to-many discussions, allowing multiple perspectives to interact without hierarchical structuring. They can overcome the limitations of human short-term memories and of paper-based aides to generating or sharing drafts of documents. CSCL should enable more powerful group cognition, which can synthesize complex interactions of ideas at different scales of collaboration, from small classroom project teams to global open-source efforts.

## A New Paradigm of Learning Research

The keynote talks for CSCL 2002 propose a new paradigm for a distinctive form of educational research. Timothy Koschmann focuses on the micro-level practices that need to be studied, while Yrjö Engeström considers the larger social contexts in which groups interact with other groups to produce learning. Koschmann offers this definition for the CSCL domain:

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.

It is clear that “meaning and the practices of meaning making” are here intended as public, observable, socially shared phenomena. This has foundational implications for CSCL research. It does not entail a rejection of quantitative studies of learning outcomes under controlled conditions. However, while these provide important information and ensure empirical grounding, they can in principle never provide the complete story. CSCL is a human science, concerned with its subjects’ own interpretations of their ideas and behaviors. Therefore, CSCL also requires qualitative studies of learning practices—such as thick descriptions that incorporate and explore the understanding of the participants in collaborative learning. As public phenomena, the meanings (learning) generated in collaboration processes can be studied directly, particularly with the help of computer logs and digitized video recordings, rather than just being inferred from post-tests.

As already suggested, the description of CSCL as concerning “the practices of meaning making in the context of joint activity” does not so much entail looking at *individuals’* practices in social settings, as it focuses on the essentially *social* practices of joint meaning making. Even when conducted by an individual in isolation, meaning making is a social act, based on culturally defined linguistic artifacts and oriented toward a potential public audience. An adequate theoretical foundation for CSCL must explain how individual practices are social without forgetting that the social is grounded in individual activities; concepts of *praxis*, *activity*, *social reproduction*, *structuration* and *enactment* begin to address this dialectic.

Koschmann’s definition of CSCL includes the study of “the ways in which these [meaning-making] practices are mediated through designed artifacts.” He refers here to CSCL technology as a ‘mediational’ artifact; as software objects designed to support collaborative learning. But this formulation can be taken more generally as raising the question of how meaning making is mediated by artifacts. This is an extraordinarily broad issue, as all human activity is meaning making, and everything in our physical, intellectual and cultural world can be considered an artifact: physical tools, linguistic symbols, cultural entities, cognitive

mechanisms, social rules... It is striking that such a fundamental issue has been so little explored. How do different classes of artifacts mediate the creation, sharing, teaching and preserving of meaning? A clearer understanding of the functioning of non-digital artifacts might help us understand how to design software to more effectively foster and convey collaborative meaning making.

### **A New CSCL Community**

The new era of learning and the new research paradigm call for a community that can integrate results from philosophy, social theory, ethnography, experimentation and pedagogy. More than this, it must be able to carry out research that integrates the foundations of these disciplines into a coherent and productive field of inquiry. As its conceptual framework and software products mature, the CSCL community must broaden to incorporate educational practitioners, teachers, trainers, lifelong learners and students around the world. The CSCL 2002 conference aims to incrementally build the foundations for such a CSCL community.

### **Four Contributions**

I would like to introduce four themes that I have come to be convinced are important for thinking about computer support for collaborative learning (CSCL):

- a. Collaborative knowledge building
- b. Group and personal perspectives
- c. Mediation by artifacts
- d. Interaction analysis

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

I will present these four themes in terms of hypotheses—or claims—that would have to be investigated further in the future:

- a. The term “knowledge building” is more concrete and descriptive than “learning” when we are interested in collaboration. It may also help to avoid the baggage of individualistic epistemology in favor of a social practice view.
- b. Collaborative knowledge building is structured by the intertwining of group and personal perspectives. One should neither ignore nor fixate upon the role of individual minds, but see them in interaction with group understandings.

- c. The construction of knowledge proceeds on the basis of artifacts already at hand—including linguistic, cognitive, cultural, physical and digital artifacts—and creates new artifacts to formulate, embody, preserve and communicate new knowledge.
- d. Naturally occurring and carefully captured examples of collaborative knowledge building—such as video recordings of classroom interactions—can be rigorously analyzed to make visible the knowledge-building activities at work, the intertwining of perspectives and the mediating role of artifacts.

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

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

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

participate in it with concrete curricular approaches, (c) design tools to support it effectively in various contexts and (d) develop methods for observing and assessing it in practice.

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

## **A. Collaborative Knowledge Building**

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

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

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

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

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

Their concept borrows explicitly from dominant forms of research in today’s scientific communities, where theories are progressively developed through professional discourse and inscription (Latour & Woolgar, 1979)—involving, for instance, peer review and critique of papers published in journals. Here, a scientific community learns about its subject matter by collaboratively building knowledge in the form of documents that gradually define a path of inquiry and successively elaborate theory while also raising issues for future deeper investigation. Conflicting theoretical perspectives are essential to the process, as

are the roles of specific participants. Discourse activities—such as questioning, proposing, arguing, critiquing, clarifying, negotiating, accusing, repairing, agreeing—are as important as the artifacts around which, through which and into which the discourse moves.

Not all important learning is collaborative knowledge building. Bereiter (2002) defines the latter in terms of the development of knowledge objects such as scientific concepts and theories. This does not include the learning of passed down facts, of practical or social skills, or of techniques of learning itself. However, social discourse about ideas—the core of knowledge building—can certainly motivate and exercise skills like reading, writing and thinking.

The thrust of collaborative knowledge building is to emphasize the construction and further development of a knowledge object that is shared by the group or “learning community.” The focus is not on personal learning by the participants, who, it is assumed, retain some of what the group discovered, deepen their collaboration skills and enjoy positive experiences of inquiry and intellectual engagement.<sup>1</sup>

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

PBL is a form of the case-based method (Collins & Stevens, 1983), but one which requires the student group to become self-reliant investigators, with the teacher or tutor only facilitating the small-group process. More generally, PBL is

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<sup>1</sup> Koschmann, in his keynote address, would no doubt prefer the term “meaning making” to “knowledge building” because “knowledge” carries Cartesian connotations of mental objects. But so does “meaning”—or any terms in which learning has been conceptualized in mainstream modern Western thought. Bereiter’s (2002) focus on knowledge objects underlines their intersubjective, publicly accessible character. His easily misinterpreted reference to Popperian ontology is best replaced by an analysis of artifacts as physical objects embodying meaning—as Bereiter now does (personal communication, June 25, 2004).

a specific approach to project-based learning (Blumenfeld *et al.*, 1991), in which a group of students conducts a project. A potential issue with project-based activities that do not adhere to a model like PBL is that tasks often get divided up so that participants cooperate (as opposed to collaborate) on the over-all project but do not collaborate on the knowledge building; they may subsequently share their individual expertise through jig-sawing (Brown & Campione, 1994), but the basic knowledge building takes place outside the group interaction.

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

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

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

## **B. Group and Personal Perspectives**

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

- Wherever meaningful symbols, representations and artifacts may be found, they are only meaningful for individual minds. Interpretation is necessary, and



that is necessarily carried out by individuals within the horizons of their personal perspectives (Gadamer, 1960/1988).

- Isolated from social interaction, physical artifacts and historical cultures, human brains are poor thinkers and could never have developed into powerful minds (Donald, 1991; Hutchins, 1996; Norman, 1993). In fact, it can be argued that modern minds are simply collections of cognitive artifacts internalized from inter-personal interactions (Vygotsky, 1930/1978). The mental is primordially a social or group phenomenon.

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

The social basis of knowledge is deeply rooted. It is not just a matter of artifacts in the world extending the limited short-term memory of individual minds, like notes scattered about as external memory traces (Donald, 1991; Hutchins, 1996; Norman, 1993). Meaning arises in the historically given, social world. We are, from the start, situated in the shared, meaningful world into which we are born and with which we are engaged (Heidegger, 1927/1996). From the infant's first inkling of intentionality in the mother's gesture (Vygotsky, 1930/1978), to the moment of mutual human recognition (Hegel, 1807/1967; Mead, 1934/1962), to the world-transforming paradigm shifts of expansive learning (Engeström, 1999), meaning springs from interpersonal interaction.<sup>2</sup>

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

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<sup>2</sup> The interpersonal nature of learning is established in the relationship of a young child with his or her parents. The social can be very personal. Throughout the duration of my relationship with my parents, they motivated my attitude toward the generation of knowledge as social praxis. I wrote the *Introduction* to these *Proceedings* on November 19, 2001, the final day of my parents' living relationship with me, and in my mind this chapter is dedicated to the memory of that relationship.

possibility of understanding a text of distant origins depends upon the author and interpreter sharing an historical horizon—one that includes the actual historical reception of the text itself.

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

Discourse is the traditional medium of knowledge building. New ideas—and their interpretation by speakers and hearers—arise in the discourse in ways that transcend any individual's role. Clearly, each word in the discourse can trivially be attributed to an individual speaker. However, the meaning of that word is defined by its position in the discourse context, that is, by its relationship to many other words (by other individuals as well as by the word's speaker) and to the Gestalt meaning of the discourse as a whole, which is the group's.

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

experience with the simulation, their previous discussion and their general world-knowledge of pulling.

When I analyzed a discourse among five middle school students and a teacher (see chapter 12), I was at first mystified by the cryptic interchanges in the transcript of a particularly intense and consequent collaborative moment. Within a matter of 30 seconds, the students exchanged 24 turns at speech, mostly consisting of sentence fragments or single words indicating disagreement or assent. It was clear that the students were intently engaged and shared a common understanding of what was taking place in the discourse: the resolution of a knotty problem for their collaborative inquiry and the achievement of a hard-fought consensus. But my retrospective interpretation of the transcript—which I developed in collaboration with experienced conversation analysts and others—required a careful reconstruction of the argumentation back several minutes as well as an understanding of the details of artifacts active in the knowledge-building context. The meaning of a given utterance was not a simple function of the words used, the prepositional content, the isolated speech act or even a conversational pair of utterances. Meaning was a shared, collaborative, interactive achievement. It was an ephemeral, rapidly evolving group perspective.

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

### **C. Mediation by Artifacts**

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

“Mediation” means that something happens by means of, or through the involvement of, a mediating object. For instance, when a student uses a technical

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

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

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

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

Vygotsky (1930/1978; 1934/1986) wanted to supplement Marx's social theory with a psychology of mediated cognition (a perspective on the individual as

intertwined with the group perspective). He extended the notion of physical artifact (tool) to encompass linguistic artifacts (symbols) as well. The individual's activity was then seen to be mediated by both varieties of artifact. The human ability to use physical and linguistic artifacts is a cultural development that allowed mankind to evolve beyond its biological basis.

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

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

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

knowledge building is experienced by the participants and may be subject to reconstruction from traces left in various artifacts, including video recordings and their transcripts.

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

One does not have to accept Vygotsky's whole approach, as sketched out here, in order to recognize the importance of an analysis of mediation and of artifacts for a theoretical framework for CSCL. Perhaps the most urgent undertaking at this time is further empirical investigation of how artifacts and their understanding actually function in concrete instances of collaborative knowledge building. For this we need a methodology of interaction analysis.

#### **D. Interaction Analysis**

Roschelle presented his analysis of two students working with a physics micro-world simulation as an instance of student learning as conceptual change, facilitated by collaborative use of a computer artifact (Roschelle, 1996). One could re-conceptualize his analysis as an attempt by the students to rediscover the meaning or affordances that were designed into the software artifact as a model of physics. The term "pull," which they interpreted and developed in this connection, was a linguistic artifact that they collaboratively constructed as a knowledge object and internalized as an expression of their learning. Roschelle used conversation analysis of video tapes as well as interviews of the students to conduct his study of the collaborative knowledge building and the internalized conceptual change.

The question of how people rediscover meaning in artifacts is an important and difficult problem. When artifacts are created, their meaning is shared and relatively accessible. The artifact functions, importantly, to capture, formulate and encapsulate that meaning. But the meaning does not remain simply available on

the surface of the artifact. As a note in the discussion database from my seminar on artifacts put it,

*Thoughts on meaning in artifacts by Bob Craig on Dec. 12, 2000:*

Do artifacts “embody meaning” or do they embody meaningful traces of human activity? ... Meaning is not “in” the artifact; rather it is “in” the total situation that includes artifacts, minds and social practices.

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

To investigate how people disclose the meaning of artifacts that they do not understand, I undertook an analysis of how the five middle-school students referred to in section B, above, struggled to uncover the structures designed into a rocket simulation (see chapters 12 and 13). I started by trying to follow the students’ knowledge-building discussion in a transcript of their discourse. But the most interesting and intense collaborative discussion was particularly hard to interpret. The student utterances did not assume the explicit form of scientific propositions of articulate arguments, nor could the conversational turns be coded as coherent speech acts (Searle, 1969).

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

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

These one-second utterances make little sense on their own. They are elliptical and indexical—like Rochelle’s “It pulls it.” By “elliptical” I mean that these are primarily sentence fragments, phrases that may complete or be completed by

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

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

In figure 11-1, Brent (circled) thrusts his body forward and shifts the group's focus to a rocket description on the monitor, about which he says "This one's different." The ensuing discussion debates what is the same and what is different about this rocket. The rocket to which "this one" is compared actually shifts here ("compare two 'n' one"), and that shift enlightens Chuck, who has resisted the teacher and the peer group, and has long tried to promote his personal perspective. Now, his "Oh" acknowledges a newfound acceptance of the group perspective.

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Figure 11-1 goes approximately here

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Figure 11-1. Students discuss a computer simulation artifact. Left to right: teacher, Jamie, Chuck, Brent, Steven, Kelly.

A detailed analysis of this transcript would make visible the knowledge-building process that took place, in which the students displayed for each other verbally and non-verbally their shifting understandings and interactively achieved the creation of shared meaning. This meaning was partially encapsulated in terms like “same” and “different,” which took on specific functions in their collaboration (see chapter 13).

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

and group perspectives by interpreting individual utterances as elements of the larger discourse and activity.

## **CSCL Foundations and Applications**

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

The perceived need of these four theoretical contributions arose while I was designing and deploying a CSCL software system named *WebGuide* (see chapter 6). This system prototyped knowledge creation and knowledge management functions that extended a conventional discussion forum. *WebGuide* investigated methods for intertwining notes in personal and group perspectives, which provided interlinked organizations of shared ideas. The effort to reflect upon the nature of the *WebGuide* software I was designing led me to a view of it as a mediating artifact. Rather than trying to analyze the complex interactions of a class using *WebGuide*, I started by looking at how students learned about a simpler digital artifact, *SimRocket* (Stahl & Sanusi, 2001)—and that led me to a growing fascination with conversation analysis and micro-ethnography. I believe that the theoretical framework that emerged from my work on *WebGuide* will prove valuable in designing and deploying the next system I will be working on, *BSCL* (see chapter 7). Perhaps it can help others as well.

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## In a Moment of Collaboration

*The interpretive analysis in this essay looks closely at an excerpt of a videotape I had made several years earlier when working on the *ESSENCE* (see chapter 2) system in a middle-school classroom. With the help of trained communication analysts, I conducted the kind of analysis called for in the preceding two chapters. It was here that I found clear evidence of group cognition.*

*In this chapter, a detailed conversation analysis of a half-minute of collaborative interaction starts to display the complexity of communication that takes place among five middle school students working with *SimRocket*, a rocket simulation software artifact. In particular, confusion about references to comparable rockets is repaired through a rapid sequence of elliptical utterances, which convey meaning only through the indexing of their interaction context. A group understanding emerges that exceeds the prior understanding of the individual participants, and that allows them to derive scientific conclusions together.*

### Analyzing Collaborative Learning

Quantitative studies of collaboration are indispensable for uncovering, exploring and documenting communication structures. However, they cannot tell the whole story. Although measures of utterances and their sequences—such as frequency graphs of notes and thread lengths in discussion forums—do study the processes in which collaborative learning is constructed and displayed, they sacrifice the meaningful content of the discussion in favor of its objective form (see chapter 10). This not only reifies and reduces the complex interactions to one or two of their simplest dimensions, but it even eliminates most of the evidence for the studied structural relationships among the utterances. For instance, the content might indicate that two formally distinct threads are actually closely related in terms of their ideas, actors or approach. Coding utterances along these characteristics can help in a limited way, but is still reductive of the richness of the data. Similarly, social network analysis (Scott, 1991; Wasserman & Faust, 1992) can indicate who is talking to whom and who is interacting in a central or a peripheral way within a network of subgroups, but it also necessarily ignores much of the available data—namely the meaningful content—that may be relevant to the very issues that the analysis explores. We will look at a set of utterances that would be impossible to code or to analyze statistically; the structural roles of the individual utterances and even the way they create subgroup allegiances only become clear after considerable interpretive effort.

The other way in which both traditional experimental method and narrow discourse analysis tend to underestimate their subject matter is to exclude consideration of the social and material context. Some approaches methodically remove such factors by conducting controlled experiments in the laboratory (as though this were not in itself a social setting) or basing their findings strictly on a delimited verbal transcript. Fortunately, countervailing trends are emphasizing the importance of *in situ* studies and the roles of physical factors, including both participant bodily gestures and mediating

artifacts. Increasingly, the field is recognizing the importance of looking at knowledge distributed among people and artifacts, of studying the group or social unit of analysis and of taking into account historical and cultural influences. In our data it is impossible to separate the words from the artifact that they reference and interpret; we will see that artifacts are just as much in need of interpretation (by the participants and by the researchers) as are the utterances, which cannot be understood in isolation from physical and verbal artifacts.

The study of collaborative learning must be a highly interdisciplinary business. It involves issues of pedagogy, software design, technical implementation, cognitive theories, social theories, experimental method, working with teachers and students, and the practicalities of recording and analyzing classroom data. Methodologically, it at least needs its own unique intertwining of quantitative and qualitative methods. For instance, the results of a thread frequency study or a social network analysis might suggest a mini-analysis of the discourse during a certain interaction or among certain actors. Interpretive themes from this might in turn call for a controlled experiment with statistical analysis to explore alternative causal explanations or generalizations. In this chapter we present an attempt to uncover, in empirical data, the sort of meaning-relationships that other methods ignore, but that might enrich their analysis.

### **What's in a Sentence Fragment?**

We naively assume that to say something is to express a complete thought. However, if we look closely at what passes for normal speech we see that what is said is never the complete thing. Conversation analysts are well aware of this, and that is a major reason why they insist on carefully transcribing what is said, not forcing it into whole sentences that look like written language. The transcript analyzed in this chapter is striking in that most of the utterances (or conversational turns) consist of only one to four words.

Utterances are radically situated. In our analysis we will characterize spoken utterances as indexical, elliptical and projective. As we will see, they rely for their meaning on the context in which they are said, for they make implicit reference to elements of the present situation. We will refer to this as *indexicality*. In addition, an individual utterance rarely stands on its own; it is part of an on-going history. The current utterance does not repeat references that were already expressed in the past, for that would be unnecessarily redundant, and spoken language is highly efficient. We say that the utterance is *elliptical* because it seems to be missing pieces that are, however, given by its past. In addition, what is said is motivated by an orientation toward a desired future state. We say that it is *projective* because it orients the discussion in the direction of some future, which it thereby projects for the participants in the discussion. Thus, an utterance is never complete in isolation. This is true in principle. To utter a single word is to imply a whole language—and a whole history of lived experience on which it is grounded (Merleau-Ponty, 1945/2002). The meaning of the word depends on its relationships to all the words (in the current context and in the lived language) with which it has co-occurred—including, recursively, the relationships of those words to all the words with which they co-occurred. We will see the importance of co-occurrences for determining meaning within a discourse later.

In analyzing the episode that we refer to as “a collaborative moment” in this chapter, we make no distinction between “conversation analysis,” “discourse analysis” or “micro-ethnography” as distinct research traditions, but adopt what might best be called “human interaction analysis” (Jordan & Henderson, 1995). This methodology builds on a convergence of conversation analysis (Sacks, 1992), ethnomethodology (Garfinkel, 1967), nonverbal communication (Birdwhistell, 1970), and context analysis (Kendon, 1990). An integration of these methods has only recently become feasible with the availability of videotaping and digitization that records human interactions and facilitates their detailed analysis. It involves close attention to the role that various micro-behaviors—such as turn-taking, participation structures, gaze, posture, gestures and manipulation of artifacts—play in the tacit organization of interpersonal interactions. Utterances made in interaction are analyzed as to how they shape and are shaped by the mutually intelligible encounter itself—rather than being taken as expressions of individuals’ psychological intentions or of external social rules (Streeck, 1983). In particular, many of the utterances we analyze are little more than verbal gestures on their way to becoming symbolic action; they are understood as not only representing or expressing, but as constituting socially shared knowledge (LeBaron & Streeck, 2000).

We worked for over a year (2000/2001) to analyze a videotape of students learning to use a computer simulation (on March 10, 1988). I say “we” because I could never have interpreted this on my own, even if I had already known all that I learned from my collaborators in this process. The effort involved faculty and graduate students in computer science, communication, education, philosophy and cognitive science as well as various audiences to which we presented our data and thoughts at the University of Colorado at Boulder. It included a collaborative seminar on digital cognitive artifacts; we hypothesized that this video might show a group learning the meaning of a computer-based artifact collaboratively, and hence, potentially visibly.<sup>3</sup>

We logged the three hours of video, digitized interesting passages, conducted several data sessions with diverse audiences and struggled to understand what the participants were up to. Despite much progress with the rest of the learning session, one brief moment stubbornly resisted explanation. The closer we looked, the more questions loomed. In the following sections, we pursue a limited inquiry into the structure of that single moment and try to understand what was meant by individual words and sentence fragments.

## **The Complexity of Small Group Collaboration**

Conversation analysis has largely focused on dyads of people talking (Sacks, 1992). It has found that people tend to take turns speaking, although they overlap each other in significant ways. Turn-taking is a well-practiced art; it provides the major structure of a conversation. The talk is often best analyzed in conversation pairs, such as question/answer, where one person says the initial part of a pair and the other responds

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<sup>3</sup> The materials from this seminar are still available as of this writing at <http://www.cis.drexel.edu/faculty/gerry/readings>. This includes logs, digitized clips, transcripts, SimRocket, reading lists and related documents. In particular, the moment itself can be viewed at:

[http://www.cis.drexel.edu/faculty/gerry/readings/simrocket/collab\\_short.mov](http://www.cis.drexel.edu/faculty/gerry/readings/simrocket/collab_short.mov).

with the

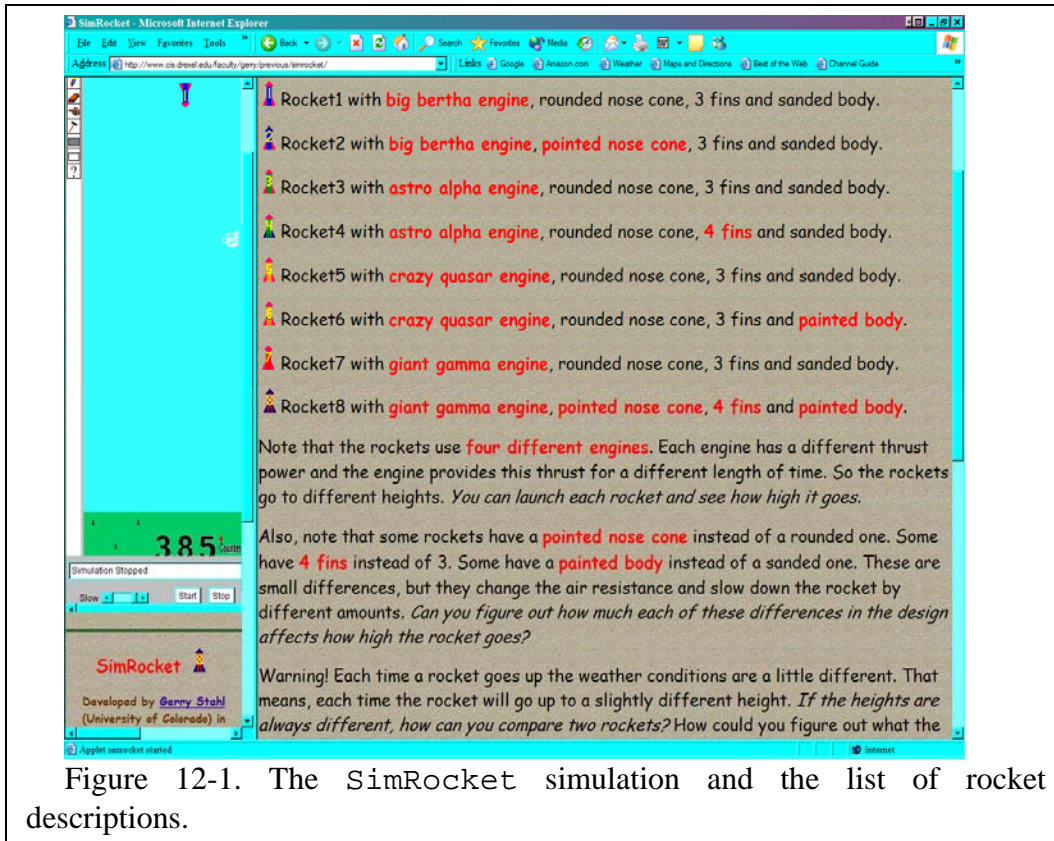


Figure 12-1. The SimRocket simulation and the list of rocket descriptions.

standard complement to that kind of speech act. These pairs can be interrupted (recursively) with other “genres” (Bakhtin, 1986a) of speech, including other conversation pairs that play a role within the primary pair (Duranti, 1998).

In much of the three-hour SimRocket tape from which our moment is excerpted, talk takes place between the teacher posing questions and one of the students proposing a response. The teacher indicates satisfaction or dissatisfaction with the response and then proceeds to another conversation pair. This is, of course, a typical classroom pattern (Lemke, 1990).

In the specific collaborative moment, something very different from the teacher-centered interaction takes place. In this tape segment, a many-to-many interaction is displayed in which meaning occurs at the group level. The structure of interaction departs from the teacher-centric dialog and teacher-interpreted meanings. It somehow overcomes the rigid sequentiality of directed turn-taking, where one person at a time seems to present their own thinking.

Let us first take a look at this special segment. The group of 11-year-old boys is discussing a list describing eight different rockets that can be used in a rocket launch simulation (see figure 12-1). They are trying to come up with a pair of rockets that can be used experimentally to determine whether a rounded or a pointed nose cone will perform better. The moment is concerned with the students noticing that rockets 1 and 2 have the identical engine, fins and body, but different nose cones, while rockets 3 and 4 differ only in their number of fins.

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Figure 12-1 goes approximately here

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This interaction takes place about an hour and a half into the classroom session. It is initiated by the teacher posing a question. For the few minutes prior, the teacher had been speaking primarily with Chuck, who had been describing some imaginary rockets he would like to design for the simulation in order to solve the problem of the nose cone. The teacher's question, accompanied by his emphatic gesture at the computer, succeeded in re-orienting the group to the list on the screen. After a significant pause, during which Chuck did not respond to this question that interrupted his train of thought, Steven and Jamie uttered responses as though talking to themselves and then simultaneously repeated them, as if to emphasize that they had taken the floor. But their response was to disagree with the teacher, something not so common in a classroom. So, the teacher restated his question, clarifying what it would take to justify an answer. Chuck responded in a confusing way, not directly answering the question, but attempting to apply the criteria the teacher put forward.<sup>4</sup>

1:21:53	Teacher	And (0.1) you don't have anything like that there?
1:21:54		(2.0)
1:21:56	Steven	I don't think so
1:21:57	Jamie	Not with the same engine
1:21:58	Steven	└ No
	Jamie	└ Not with the same
1:21:59	Teacher	With the same engine ... but with a different (0.1) ... nose cone?= └ =the same=
1:22:01	Chuck	└ =the same=
	Jamie	└ =Yeah,
1:22:02	Chuck	These are both (0.8) the same thing
1:22:03		(1.0)
1:22:04	Teacher	Aw └ right
1:22:05	Brent	└ This one's different

The teacher paused at 1:22:03, encouraging student discussion, and Brent jumped in, cut the teacher off, and lurched forward and pointed at a specific part of the list artifact (see figure 11-1 in chapter 11), while responding to the teacher's quest for something "different." For the next 16 turns, the teacher was silent and the students rapidly interacted, interjecting very short, excited utterances in a complex pattern of agreements and disagreements. From the conversational structure, one sees that the standard, highly controlled and teacher-centric dialog had been momentarily broken and a more complex, collaborative interaction had sprung forth. Normally reticent, Brent excitedly rocked forward off his chair, pushed through a line of students, filled a void left by the teacher, and directed attention pointedly at the artifact.

Dramatically transforming the stage within which talk takes place, Brent had signaled an urgent need to resolve some disturbing confusion. The importance of this move was evidenced in the bodily behavior of Kelly, a student who said nothing during the entire episode. Kelly was slouched back in his seat, with his head rolling around distractedly, up

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<sup>4</sup> Note on the transcription: Numbers in parentheses indicate length of pause in seconds. Brackets between lines indicate overlap. = between utterances indicate lack of pause between them. Underline indicates verbal emphasis.

to this point in the transcript. As Brent leaned forward, Kelly suddenly perked up and also leaned forward to pay attention to what was transpiring.

At 1:21:53 the teacher opened a conversation pair with a question. It was intended as a rhetorical question, that is, as one that was expected by the asker (the teacher) to make the conversation partner (the group) see that there was something “like that there” and to answer in the affirmative, signaling that they had seen what the teacher was indicating. We can see that it was intended as a rhetorical question because the negative answers supplied by the students were not accepted. As the first part of an adjacency pair addressed to the plural “you,” the teacher’s utterance spoke to the students as a group and called for a response from the group. Various students tried repeatedly to produce the projected response on behalf of the group. The three students who tried to answer in the negative—first Steven and Jamie simultaneously, and later Chuck—repeated their answers, as if to re-assert answers which the teacher’s question was not projecting. Rather than accepting these answers, the teacher rephrased the question and paused again for the projected affirmative answer.

Brent responded to the conflict between the expectation given by the rhetorical question and the attempts by the other students to give a negative answer. The section of transcript discussed next can be seen as an attempt by the group to resolve this conflict and provide the affirmative answer that the teacher’s question sought, finally completing the interrupted conversational pair of (rhetorical) question and (affirmative) answer.

## The Problem

Brent interrupted the teacher with, “This one’s *different*.” The word “*different*” referred back to the teacher’s last statement. The teacher’s full question, elaborated in response to Steven and Jamie’s disagreement was: “And (0.1) you don’t have anything *like* that there? . . . With the *same* engine but with a *different* (0.1) nose cone?” In the meantime, Steven and Jamie had both picked up on the teacher’s term “*same*,” as had Brent.

1:22:05	Brent	└ This one’s different ((gestures with pen at computer screen))
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The teacher had used the terms, “same” and “different” to clarify what he meant by “like.” In rhetorically asking, “Don’t you have anything *like* that there?” The teacher was suggesting that the list of rockets (“there,” where he was directing their attention) included a rocket whose description was “like” the rocket they needed, namely one that had the same engine but a different nose cone from the one with which they would compare it.

The teacher’s original statement at 1:21:53 was *elliptical* in its use of the term “like.” It assumed that the audience could infer from the context of the discussion in what ways something (“anything” “there”) would have to be in order for it to be like the thing under discussion (“that”). After two students responded that they could not see anything like that there, the teacher tried to explicate what he meant by “like.” He did this by picking up on Jamie’s “Not with the same engine” and defining “like” to mean “with the same engine, but with a different nose cone.” Scientific talk tries to avoid the elliptical ways of



normal conversation. Throughout the session, the teacher modeled for the students this explicit way of talking, often taking what a student had stated elliptically and repeating it in a more fully stated way. In this instance, the teacher is doing just that. Sometimes one of the students would pick up on this and start to talk more explicitly. Here, Brent picked up on the term “different” as a key criterion for determining likeness.

Of course, the problem for us as researchers is that Brent’s exclamation, “This one’s different,” is itself elliptical. In what way is “this one” different?

## The Confusion

In analyzing this passage, there is also the interpretive problem of reference or *indexicality*. Brent has just pointed at the list of rocket descriptions, but it is impossible to tell from the video data which description he indicated. Even if we knew which one Brent pointed to, his utterance does not make clear which other rocket he was comparing with the one to which he pointed. We have to deduce the answers to both these questions from the ensuing discussion, to see how the participants themselves took the references.

Jamie’s immediate follow-on utterance began with “Yeah, but,” indicating a response that was partially supportive. Because we know that Jamie was responding to Brent, we know that Jamie’s use of “it” referred to Brent’s “this one.” Chuck, in turn, built on Jamie’s response and reclaimed the floor by interrupting and completing Jamie’s incomplete utterance of the term “nose cone.” So, Chuck’s subsequent utterance—which he tied to the preceding phrase with “but”—uses the word “it’s” to refer to Brent’s “this one” as well.

1:22:06	Jamie	Yeah, but it has same no...
1:22:07		(1.0)
1:22:08	Chuck	Pointy nose cone=
1:22:09	Steven	=Oh, yeah=
1:22:10	Chuck	=But it’s not the same engine

At this point we see the conflict begin to be stated. Chuck’s “but” suggested a disagreement with Brent and possibly with Jamie also. In the next second, both Jamie and Brent came back with “yes it is,” showing that they took Chuck’s comment to be a clear disagreement with what they were saying.

Kelly’s non-verbal behavior again indicated that something unusual was happening: he rocked forward onto his elbows to follow events more closely. He stayed in this position for the rest of the moment.

At this point in our interpretation, we see several shifting factions of opinion. At first, all the students seemed to disagree with the teacher. Following Brent’s bold gesture, some of the students seemed to disagree with other students. In this analysis, we are not yet able to fully work out the basis of this disagreement because of the elliptical and indexical nature of the utterances that form the data.

We can overcome the problem of the elliptical—but not the indexical—character of the utterances by looking closely at how the individual utterances built off of each other, repeated the same words, or used conjunctions like “but” or “yeah” to signal continuity of topic. However, it is harder to know, for instance, which rockets are indexed by pronouns

like “it.” It seems likely that Jamie and Chuck were, in fact, indexing different rocket descriptions with their use of the pronoun “it.” This would certainly cause confusion in the discussion because the repeated use of the same word should signify commonality of reference. To determine which rockets they were each indexing in their utterances, we will have to continue our interpretive effort.

## The Repair

In the seconds that followed the previous transcription, Jamie and Brent stated virtually the same thing simultaneously. This indicates that the state of the group discourse—from the perspective in which Jamie and Brent were viewing it—must have been very clear. That is to say, the network of indexical references, as interpreted from Jamie and Brent’s utterances, is uni-vocal. Within this set of references, Chuck’s claim that “it’s not the same engine” is clearly wrong. Jamie and Brent insisted that “it” is the same engine.

1:22:11	Jamie	Yeah, it is, =
1:22:12	Brent	=Yes it is,
1:22:13	Jamie	└ Compare two n one
	Brent	└ Number two

Jamie and Brent supported their counter-claim precisely by clarifying the references: they were talking about similarities and differences between rocket number two and rocket number one on the list in the simulation artifact.

Jamie’s imperative, “compare two and one,” is first of all an instruction to Chuck to look at the descriptions of rockets 2 and 1 on the list. At the same time, it is a reminder that the purpose of the whole discourse was to conduct a comparison of rockets in order to determine the best nose cone shape. Jamie’s utterance served both to propose an explicit set of indexical references for the problematic discussion and to re-orient the discussion to the larger goal of solving a specific scientific task. His utterance thus served to state both the indexical and the *projective* basis of the discourse. He was saying that the group should index rockets 1 and 2 in the list comparison so that they could then conduct a comparison of rockets 1 and 2 in the datasheet artifact as their projected future task.

Jamie and Brent solved our task of interpreting the indexical references! Of course, we might still want to try to reconstruct the networks of references that different participants had at different points in the discourse. We would thereby be retrospectively reconstructing the process of construction that the discourse originally went through to reach this point. We would be “deconstructing” the discourse.

If we go back to the minute of discussion between the teacher and Chuck that preceded our transcript, we indeed find the source of the confusing references. Chuck had switched the discussion from nose cones to fins and had in fact solved the problem of how to determine the best rocket fin configuration. He said to compare rockets 3 and 4, which were identical, except that rocket 3 had three fins and rocket 4 had four fins. Then Chuck wanted to return to the problem of nose cones. He proposed making the simulation software modifiable by users so that he could either change the nose cone of rocket 3 or

4, or else change the engine of rocket 2 to match the engine of rockets 3 and 4. This would have created a pair of rockets with the same engine as his baseline rocket (3 or 4) but with different nose cones. So, Chuck was actually then already following the theoretical principle of only varying one attribute at a time. However, his description of the changes that he would make got quite confusing—plus, it made unrealistic assumptions about the software.

So, the teacher’s remark at 1:21:53, directing Chuck and the others back to the list on the screen, can be seen as a *projective* attempt to have Chuck recognize that rockets 1 and 2 could be compared as is, without changing one of them to be comparable to 3 or 4. In other words, the list had this built-in structure—that Chuck was not seeing and taking advantage of—that it had been organized to solve the problem of rocket comparisons. Unfortunately, because the discussion had been focused on rockets 3 and 4 as the basis for comparison, none of the students could see at first that 1 and 2 met the criteria. As Jamie said, there was no rocket with a pointed nose cone, “not with the same engine”; we can see now that the word “same” referred to the same engine as in rockets 3 and 4.

When Brent pointed to what must be rocket 2 and said, “This one’s different,” his utterance referred to the fact that rocket 2 had a pointy nose cone, which was different from all the other rockets. At that point in the transcript, Brent’s and Jamie’s utterances must be taken as comparing rocket 2 to rocket 1, because, when Chuck kept insisting that “it’s not the same engine” (meaning that rocket 2’s engine was not the same as the engines in rockets 3 and 4), Brent and Jamie retorted “yes it is” and explicitly referred to rockets 1 and 2. As they repeated that they were looking at descriptions of rocket 2 and another rocket with the “same” engine, even Chuck gradually aligned with the reference to rockets 1 and 2. By looking back at the situation prior to our moment in this way, we can reconstruct how our moment developed out of its past, and we can determine a consistent and meaningful interpretation of the utterance references, as understood from the perspectives of the different participants.

## The Resolution

In the final segment of our transcript Chuck responded to Jamie’s clarification. When Jamie said “compare two and one,” Chuck actually turned to the computer screen and studied it. With gradually increasing alignment to what Jamie was saying, Chuck said tentatively, “I know.” This is the first time during this episode that his utterances were agreements. Jamie went on to instruct him on how to make the comparison of rockets 1 and 2 by noting how they “are the same.” Chuck’s “Oh” response indicated a change in interpretation of things. Brent made even more explicit how Jamie’s “are the same” was to be taken, namely that both rockets had the same kind of engine.

1:22:14	Chuck	(0.2) I know.
1:22:15	Jamie	(0.2) Are the same=
1:22:16	Chuck	=Oh
1:22:17	Brent	It’s the same <u>engine</u> .
1:22:18	Jamie	So if you $\left\{ \begin{array}{l} \text{compare two n one,} \\ \text{Oh yeah, I see, I see, I see} \end{array} \right.$
1:22:19	Chuck	
1:22:21	Jamie	(0.8) Yeah. Compare two n one. So that the rounded n- (0.1) no the <u>rounded</u> one is better. Number one.

Jamie repeated his double-edged imperative to “compare two and one.” But he preceded it with “so if you.” He was not only telling Chuck to look at the two descriptions and to compare them, but was also saying that if he did this then he could go on and do something in the future, namely he could compare the data that the students had collected in the previous hour for these two rockets and determine the best nose cone design. While Chuck was conceding that the descriptions of rockets 1 and 2 met the criteria that the teacher spelled out at the start of the moment, Jamie started to look over the data sheet that he had been holding ready at hand during the whole conversation and had brought up to his line of sight at 1:22:13. (Steven had also gone to retrieve his data sheet at 1:22:15, after Jamie first said, “compare two and one” and then checked the list on the screen for a moment.) Then, Jamie announced the findings from the data. In the final utterance at 1:22:21, Jamie compared the data from rockets 2 and 1, but not their descriptions. He announced that the rounded nose cone was better based on its performance data. He stopped himself in the middle of this announcement to check his analysis, which required combining information from the list and the datasheet. Finally, he linked the conclusion about the rounded nose cone to the rocket description (“number one”). This not only resolved any possible conflict about the references of the discussion, but showed how they worked to solve the larger task that had been projected for the discourse.

At the end of our collaborative moment, a quiet consensus was reached. Jamie and Steven had moved on to the data sheets and everyone else was looking intently at the list, having acknowledged the teacher’s rhetorical question, “And you don’t have anything like that (rocket 1 and 2 descriptions, with the same engine and different nose cones) there (in the list)?” At that point, all the references were aligned with those of the teacher’s original question, which brought an end to the breakdown of references and allowed the group to affirm the question and move on to solve their task using the newly comprehended list artifact.