Explorations in the Learning Sciences, Instructional Systems and Performance Technologies

Timothy Koschmann *Editor*

Theories of Learning and Studies of Instructional Practice

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Acknowledgments

The production of this volume has been a long and arduous undertaking and we have many people to thank for their help along the way. The book is based on a workshop that took place in the fall of 2003 at the Allerton Conference Center, a country retreat maintained and operated by the University of Illinois at Urbana-Champaign. It provided a pastoral setting for our workshop and we are grateful for the warm hospitality we were shown there. To produce an enduring record of our discussions, the sessions at Allerton were videotaped. The recordings were done by Rochelle Robertson, Denise Kaye and Ferhan Dereboy. Alan Zemel helped with transforming their footage into a DVD set that was subsequently distributed to the workshop participants.

Since the workshop, we have worked slowly and methodically toward the goal of developing our discussions at Allerton into the book that you now hold. Its structure, consisting of linked target chapters, commentaries, responses and synthesis chapters, created a network of dependencies that worked against completing the project in any simple or straight-forward way. Jean Afflerbach maintained the authors' webpage as the manuscripts went through multiple revisions. Lesley Barfield helped out on indexing. We have worked with a variety of acquisition editors over the course of the project and we thank them all for their patience and support. We especially thank Saranya devi Moorthy of Integra Software Services for her diligent work in fashioning a beautifully integrated volume from the many scattered pieces that comprised this project.

Support for the Allerton workshop was provided through a grant from the Division of Research on Learning in Formal and Informal Settings (DRL) under the Directorate for Education and Human Resources (EHR) of the National Science Foundation (Grant No. 03-13990). The idea of organizing a workshop was initially discussed with Nora Sabelli. After she left NSF, the project was overseen by John Cherniavsky. It probably goes without saying, though they would wish for me to say it anyway, the opinions expressed within these covers are those of the various authors and not necessarily those of the Foundation . . .

We thank one and all for their efforts toward bringing this ambitious project to its current state. I say 'current state' rather than 'completion' because I see the publication of this book, not as the end of the story, but rather as the beginning of a new phase of an ongoing conversation. We are pleased and excited to see the set of issues initially explored at Allerton now being brought to the attention of the broader educational research community.

Springfield, IL Timothy Koschmann

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Part I
Introductions

Chapter 1
Theorizing Practice

Timothy Koschmann

Practice as Treatment

This is a book about an attempt to change the way math was taught in a particular classroom. More specifically, it is about our methods for studying such changes in practice and the theories/models that inform these methods. The title of this chapter plays on our everyday usage of the terms *theory* and *practice*. In education, of course, we have two orders of theory – theories of learning and theories of instruction. Theory and practice come into contact in the context of theories of instruction – we have theories about what teachers *should* do and observations of what they actually *do* do. Theory and practice, therefore, are conventionally viewed as opposed – theory standing prior, logically and chronologically, to practice, practice inevitably becoming theory's corrupted realization. In this volume, we seek to develop new ways of relating theory to practice and practice to theory. The book focuses upon the actual practices by which teaching is done and how contemporary theories of learning might help us understand those practices. In this way, it seeks to provide a foundation for future practice-based inquiry in education. It is designed to address a pair of related methodological questions: How might we go about studying instructional practice in a rigorous way and what role would theories of learning play in such investigations?

Our model for experimental research in education today can be traced back to E.L. Thorndike, the father of contemporary educational psychology (Walberg & Haertel, 1992). Learning, for Thorndike, consisted in strengthening connections between stimuli and responses, an approach rooted in British Associationism (Sahakian, 1975). He postulated that learning is a lawful process, i.e. that with adequate knowledge of the environmental circumstances one can predict which stimuli will become associated with which responses. Things were real for Thorndike only to the extent that they could be measured.[1] The strengthening of bonds between

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stimuli and responses, however, is not an event that could (or can) be observed or measured neurophysiologically. Thorndike overcame this limitation by stipulating that, though learning itself is not available to direct measurement, it has effects on behavior and these *are* subject to measurement. Much of Thorndike's career was devoted to calibrating appropriate scales for measuring such changes (Mayer, 2003). In this way, learning and assessment became inextricably bound in the program of study Thorndike founded. For the educational psychologist, learning is a purely operational construct – it is what the test instrument reveals. Thorndike believed this treatment of learning could provide the basis for a program of instructional improvement. His program employed an experimental design in which the instructional innovation serves as the treatment variable and learning, operationally defined, as the dependent variable. The task, then, becomes one of sorting treatments that are effective from those that are not. Thorndike's vision of a new science of instruction has now been realized. Its name is educational psychology and it has become the queen discipline for research in education. His approach has indeed come to stand for what counts as science in educational research today.[2]

Over the course of the intervening century, the technologies of assessment have evolved into increasingly more sophisticated forms. And as new and more powerful tools for hypothesis testing and statistical model building were introduced, they were swiftly appropriated into the service of this program. In the meantime, theories of learning were also changing. By mid-century, the acquisition of simple associations was seen by psychologists as an inadequate treatment of learning. Issues of understanding, representation, and use came to the fore (Pressley & Roehig, 2003). Studies of experts and novices, for example, revealed that, "expert's knowledge is connected and organized around important concepts . . .; it is 'conditionalized' to specify the contexts in which it is applicable; it supports understanding and transfer (to other contexts) rather than only the ability to remember" (Bransford, Brown, & Cocking, 1999, p. 9). Learning, by this view, came to be seen as the construction of representations and models similar to those held by experts. Mental representations, however, are no more subject to direct study than Thorndike's changes in bond strengths. As a result, cognitive psychologists, like the earlier learning theorists, must rely upon learning's traces to warrant its occurrence. So, though these newer, cognitivist treatments came to supplant the older S-R theories, the methodological approach pioneered by Thorndike was preserved.

The overarching goal of Thorndike's program was to bring about fundamental reform of instruction through incremental improvements in practice, of identifying what works. Gage (1963) described the work of educational psychology as existing on a continuum from tightly-controlled laboratory studies to broad-scale educational reform (see Fig. 1.1). Starting from the left, we find experimental studies of learning, studies with no immediate connection to the practicalities of the classroom. As we advance to the right, experimental control declines as the innovation is moved out into the field. Gage's continuum displays the versatility of the Thorndikean program. Progressing from the laboratory to the classroom, at every transition, the same instrumental framework can be applied to assess the innovation at ever larger scales of implementation.

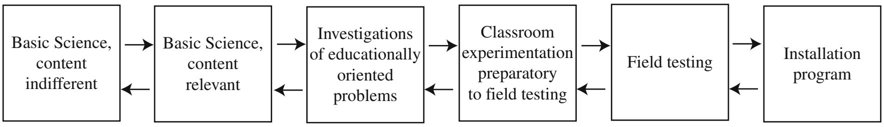

Fig. 1.1 Gage's (1963) continuum of settings and stages for research on teaching (Used with permission of the American Educational Research Association)

Unfortunately, the "what works" approach has never quite realized its promise. In the natural sciences, the use of clinical evaluation methods similar to those used in educational psychology have led to dramatic improvements in practice. While agriculture and medicine have been revolutionized through the introduction of new fertilizers and pharmaceuticals, we have no success stories in education that rival, for example, the introduction of penicillin in medicine. The problem, or at least part of the problem, may lie with the way in which the Thorndikean program engages instructional practice.[3]

Within Gage's continuum, the treatment condition at each stage is presumed to involve a change in practice. But how are we to assure ourselves, when we reach the upper reaches of the continuum that we are still working with the same practice as that with which we started? Furthermore, the methods of hypothesis testing employed in educational psychology assume that treatments will be applied uniformly within experimental groups. When the treatment is a practice, however, and one introduced into many classrooms in many schools, how do we satisfy the presumption built into the experimental design that it be the same for all subjects? Indeed, what meaning do the conventional defining features of scientific inquiry – prediction, replicability, falsifiability – hold when we lack an empirically-based description of our treatment conditions?

The tradition of research in educational psychology going back to Thorndike's pioneering efforts and carrying forward to the present has averted its eyes from instructional practice focusing instead upon its putative effects. Theories about instructional practice may be advanced and tested experimentally, but practice itself is never systematically studied in its own right. One consequence is that we are left functionally inarticulate with regard to the practical details of the very changes that we would like to see taken up by teachers. We need, therefore, to re-think our research priorities. Where the prevailing program focuses exclusively on improving outcome measures, we need to develop a new research agenda, one that addresses the importance of making competent instructional practice visible.

Practice as Topic

Before engaging the question of how we might undertake a more practice-based approach to studying instruction, we might ask, just what do we mean by *practice* in the first place? For the purposes of the current discussion, we are simply using the term to describe that which participants, teachers and learners, can be observed to do. By Berliner's reckoning, the period of disdain began with the shift to place educational research on a more "scientific" footing. But assuming Berliner is correct and educational researchers are now developing a newfound respect for practice, just how are we to go about studying it? How, more generally, do we begin to construct a real science of instructional practice?

A reasonable approach might be to build on the scholarly traditions that already address practice as an object of discovery rather than a given. Practice, after all, has not been totally overlooked as a research topic within the social sciences or even in educational research.[4] However, those efforts that have taken up instructional practice as their primary topic have tended to be overshadowed by the more prominent and vastly better funded work conducted within the Thorndikean tradition. They also have their roots in disciplinary traditions (i.e., anthropology, sociology, linguistics) at some remove from the psychometric tradition upon which the Thorndikean program is based.

Before engaging the question of how we might undertake a more practice-based approach to studying instruction, we might ask, just what do we mean by *practice* in the first place? For the purposes of the current discussion, we are simply using the term to describe that which participants, teachers and learners, can be observed to do. Practice, in short, is attested conduct.[5] The goal of a practice-based approach to studying instruction, then, becomes one of giving an accurate account *in detail* of what the practices were and what they accomplished. Just producing accurate descriptions of instructional practices may sound simple, but there are a number of complicating issues.

Practices come, to paraphrase Macbeth (2005),[6] with "worlds attached." Linguists refer to terms like *here*, *how*, and *them* as "shifters" because their meanings change depending on when and where they are used. Practices share this property. They both constitute and are constituted by their context. This raises certain issues for the ways that we might study them. When learning is reduced to a simple test result, the "attached world" is allowed to slip away. To begin to understand how teachers and learners understand what they are doing together will necessitate carefully study of the circumstances under which their practices are produced.

Practice is the substrate from which all forms of recognizable action and activity are composed. Teachers and students interacting in classrooms draw on a variety of practices – practices of seeing, of showing, of talking, correcting, assessing, affiliating, etc. Some are peculiar to the classroom and have a particular institutional character, while others are more fundamental and are employed across a wide variety of settings. Instructional settings are especially valuable sites for studying practice because what counts as competent production must, of necessity, be placed on display there. Consider again the example of a teacher interacting with a classroom. Let us say the lesson involves learning to read and produce graphs. The teacher's actions are designed to foster certain desired practices on the part of the students; they are designed to introduce the students to accepted ways of working with these formal representations. In rendering some target practice visible for the students, however, the teacher, as a skilled practitioner, presents it for our inspection as well. Moreover, the practices whereby this rendering gets done are also made available to analysis. We might learn things, therefore, about what it means to "read" a graph by studying interaction in this classroom. At the same time, however, we might also learn something about how practice, any practice, is produced instructably. All instruction has this dual nature – it must be understood both in terms of the practices through which it is produced and of the practices it is designed to engender.

Theories of Learning and Research on Instructional Practice

Gee (2005) discussed how a particular research question related to linguistics might be addressed "directly." He wrote:

> The only way to investigate it is to formulate it in terms of the language licensed by some theory of the domain and, then, use the procedures ("methods") of that theory's approach to answer the question. We are never looking *directly* at language or grammar. We are looking at language or grammar as it has first been specified by a given theory and its apparatus for formulating and attempting to answer questions in the domain. (p. 12, authors emphasis)

Our concern here is not with grammar, of course, but rather with the embodied practices of doing instruction. But by substituting "instruction" for "language and grammar," the Gee quote invites us ponder what it might mean to study instructional practices "directly."

Hanson (1961) observed that it takes a theory "to observe phenomena as being of a certain sort, and as related to other phenomena" (p. 90). The tradition in the philosophy of science pre-Kuhn was to assume a sharp distinction between observation and theory language (Hacking, 1983). Kuhn challenged this distinction, however, denying the existence of theory-neutral observational reports (Sharrock & Read, 2002, p. 17). The argument made by Gee with reference to language use and here extended to instruction is that observation presupposes some sort of technical vocabulary, a vocabulary that has its basis in theory.

The roles and uses of theory in psychology differ sharply from the ways in which theories are employed in the physical sciences. A physicist, for example, might advance a theory that a certain kind of sub-particle *should* exist even though one has never been seen. Empirical work could then be undertaken to test whether or not the theory is correct. Thagard (1992), however, has argued that psychology has produced no theories, at least none of this validatable type. What it has developed instead are better described as "approaches." By Thagard's account, these are "more general and diffuse than theories that explain identifiable sets of facts" (pp. 225–226). This description of theory in psychology would appear to apply as well to how theories of learning are used in educational research. Such theories serve as axioms, specifying what we take learning to be, rather than testable conjectures. Nor do they necessarily lead to recommendations for how instruction ought to be conducted. The goal of the early learning theorists had been to develop general laws from which principles of instruction could be derived, but, by the middle of the twentieth century, this ambition had all but been abandoned. As Hilgard (1964) conceded, “Learning theory will not dictate instructional practices any more than the principles of thermodynamics dictate whether airplanes shall be driven by propellers or jets” (p. 403). Consequently, theories of learning become relevant today as a means of rationalizing proposals for change in instruction, but do not, strictly speaking, dictate the shape of those proposals.

We return now to the central issue of the volume, namely what role do theories of learning play in conducting investigations of instructional practices? This opens into a variety of other, closely related questions. What alternatives to Thorndike’s connectionism and cognitive representationalism exist as contemporary formulations of learning? How do they relate to each other and what aspects of these formulations are currently considered to be controversial? How do such treatments inform the ways in which we see instruction? Are our observational reports of instructional practice in Gee’s (2005) terms, “licensed by” our theories about what learning is? Are these theories part of the “apparatus for formulating and attempting to answer questions” (ibid) about instruction? Or do they have any bearing at all on our understanding of instructional practice?

The Organization of the Book

A NSF-sponsored workshop was conducted in the fall of 2003 at the Allerton Conference Center in Monticello, Illinois to begin to grapple with these issues. It was organized in three sections each dedicated to a particular contemporary formulation of learning. Our task, begun at the workshop and continued in the pages of this volume, was one of sorting out the differences among the treatments and determining the significance of these differences for the study of instructional practice. For each theoretical approach, a prominent author was invited to prepare, in advance of the workshop, a position paper outlining the critical features of that particular formulation. To keep our discussions concrete, the authors of these papers were asked to demonstrate how they might apply their theory of learning to the study of an actual sample of instructional practice. We were particularly interested in exploring how the different theories of what constitutes learning might illuminate different aspects of classroom activity.

Rich Lehrer and Leona Schauble generously permitted us to use data from one of their research projects as material for discussion at Allerton. They had designed an innovative curriculum, one combining mathematics and science education, to introduce elementary school students to the basics of variability and distribution (see, for example, Lehrer & Schauble, 2000, 2002, 2004, 2005). At the time that the materials discussed at the Allerton workshop were collected, they had developed this curriculum to the stage of “classroom experimentation” on Gage’s continuum. Lehrer and Schauble had worked for an extended period of time with a particular teacher and his students and constructed a corpus of recordings and exhibits from his classroom.

Each of the position papers was presented as a proposal for how the Lehrer and Schauble classroom materials might be studied in the light of a particular theoretical perspective. Grimshaw introduced the expression "comparative analysis" (Grimshaw, Feld, & Jenness, 1994, p. 21) to describe an organized effort to study a common set of materials from different analytic perspectives. The Multiple Analysis Project (MAP) which he organized was one example, as was an earlier effort by a diverse group of researchers to jointly study a psychiatric interview (McQuown, 1971).[7] Rather than describe the activity undertaken at Allerton as a comparative analysis, we prefer to refer to it as a *collaborative* analysis to emphasis our orientation to building an understanding the selected materials together.[8] There have been a few earlier attempts to perform analyses of this sort in education (e.g., Koschmann, 1999; Sfard & McClain, 2002; Stahl, 2009).[9] Our specific interest here was in seeing how different approaches might build upon each other to produce an enhanced understanding of what took place in the classroom in which Lehrer and Schauble introduced their experimental curriculum.

In the chapter that follows, they provide an introduction to this classroom. The three lesson periods examined at Allerton came midway into Lehrer and Schauble's first run-through of the curriculum. Prior to the workshop, all participants were provided with video recordings of the three lessons (150 min total), digital images of student-produced work and researchers' field notes. The participants were free to select for themselves just what they would like to analyze from this data set.[10] After the workshop, all excerpts referenced in one or more of the chapters were compiled and carefully transcribed. They can be found in Appendix B at the back of the book. These transcripts, along with included samples of student work and selected images (see List of figures), afford opportunities for the reader to participate in the collaborative work of making sense of what can be observed to have happened in the classroom.

The three position papers presented at Allerton were revised and re-written as the target chapters that anchor the three primary sections ("The Situated Action Perspective," "A Dialogic Theory of Learning," "Transactional Inquiry") of this volume. In each section, scholars were recruited to comment on the associated target chapter. Scholarship in education today derives from a variety of disciplinary traditions and encompasses a wide diversity of interests. Given our concern with the details of social practice, we thought it important to include in each section at least one scholar with a background in studying social interaction. Similarly, the prominent role afforded cognitive theorizing in educational research today (c.f., Bransford et al., 1999; Pressley & Roehig, 2003) made it imperative to have at least one commentator evaluate each target chapters from that perspective. To round out each section, we also included researchers who could comment from historical/philosophical viewpoints and from the perspective of teachers and teacher educators. Some commentators – Paul Cobb, Kay McClain, Bruce Sherin, Rupert Wegerif – were recruited after the workshop. Paul Feltovich and Chuck Goodwin participated in the discussions at Allerton, but did not prepare chapters for this volume.

The first position paper was presented by James Greeno and is presented as Chapter 3. In earlier writing, he described how learning might be studied from a "situative perspective" (Greeno & MMAP, 1998; Greeno & Moore, 1993). It is an approach based in part on Lave's (1988) social practice theory. In his chapter, Greeno develops a formulation of learning based on patterns of participation and development of participatory identities in systems of social practice. There are three key concepts to this treatment: *communities of practice, legitimate peripheral participation, and participants' developing identities*. Lave and Wenger (1991) defined a *community of practice* as "a set of relations among persons, activity, and world, over time and in relation with other tangential and overlapping communities of practice" (p. 98). They stressed that this definition does not necessarily imply "co-presence, a well-defined, identifiable group, or socially visible boundaries," but does require "participation in an activity system about which participants share understandings concerning what they are doing and what that means in their lives and for their communities" (p. 98). They went on to describe *legitimate peripheral participation* as opportunities extended to newcomers to a community of practice to learn, that is "of both absorbing and being absorbed in the 'culture of practice'" (p. 95). By stipulating that "learning occurs through centripetal participation in the learning curriculum of the community" (p. 100), they made clear that they were conceptualizing learning as a social rather than psychological process. It should be observed that learning is not simply construed as joining or entering a community of practice, however, but rather represents continuous changes in the nature of participation over time. Greeno (Greeno & MMAP, 1998) highlights this point in defining a *participant′s identity* as, "regularities of an individual's activities, in a trajectory that spans participation at different times in a community and participation in different communities" (p. 6), a definition he credits to Wenger (1999). Rather than looking for evidence of change within heads, therefore, the situative perspective looks for change in social practice.

Suchman (1993) observed that the situated perspective is not a unitary position, but rather defines a family of loosely allied critical perspectives. The version of situated action advanced by Greeno in his target chapter is an admixture of social practice and information processing theory. Greeno's examination of the materials from the Lehrer/Schauble classroom focuses on the power of representation. Macbeth (Chapter 4) offers an alternate version of situativity, one that "points in the general direction of a grammar of action" (p. 76). He writes, "if we posit a world of situated action, then we posit a world of competent social action" (p. 76). Writing from this perspective, he provides an alternative reading of some of the fragments from the classroom. As one of the founders of the Cognitive Science Society and an educational researcher with early interests in situated learning (cf., Brown, Collins, & Duguid, 1989), Allan Collins (Chapter 5) is uniquely qualified to comment on the cognitive features of Greeno's position paper. He takes up the theme of competence, first raised in Macbeth's commentary, but applies it to the topic of representation featured in Greeno's chapter. Collins explores some of the requirements for design if we take representational competence as an instructional goal. Greeno suggests that efforts to find a way to reconcile the cognitive and the social can be likened to the quest for the Holy Grail in educational research. He proposes that the situative approach might represent a solution to this problem. Eric Bredo (Chapter 6) calls this into question, however. He begins by observing that, rather than achieving an integration of the cognitive and social, what Greeno's situative approach offers is an account of "content" and "control." Bredo argues that this results in a static and, thereby, distorted picture of the situation. He focuses, in particular, on Greeno's use of the term "positioning" which would seem to have a dynamic character. But, because control/social relations are treated as static influences on content/cognition, identities become bound. According to Bredo, this leads to a form of analysis that fails to see social relations and cognition as dynamic and mutually constitutive. Kay McClain's commentary (Chapter 7) raises the issue of teacher learning. There were many kinds of learning visible in the Lehrer/Schauble classroom – students learning about natural variation and how to represent data, teachers learning how to participate within the curriculum as designed, researchers learning how it might best be organized. Writing as a math education researcher and a teacher educator, McClain explores what kinds of teacher learning would be necessary in the observed setting and asks how Greeno's situative perspective might help us find it. Greeno provides a response to the commentaries.

The second position paper at the Allerton workshop was presented by James Wertsch and Sibel Kazak. In earlier writings, Wertsch (1991, 1998, Wertsch & Smolka, 1993) had developed what may be termed a *dialogic theory of learning*. Viewed dialogically, learning is seen as a form of meaning making emerging from different "voices" coming into contact (Wertsch, 1998). There are a number of implications of conceptualizing learning in this way. First, like the situated action perspective, such a move has the effect of de-centering learning, locating it in social interaction rather than in the head of any one learner. Second, it effects a shift from viewing learning as a discrete achievement or event to a more dynamic and process-based account. Third, since meaning for theorists like Bakhtin is always locally determined, dialogicality treats the content of learning, not as given, but rather as emergent, non-deterministic, and contingent. Finally, Wertsch (1998) described how utterances can be analyzed with reference to the culturally-supplied mediational structures, that is social languages and speech genres, of which they are instantiations.

In Chapter 9, Wertsch and Kazak expand upon this perspective focusing on mastery in the use of certain sign vehicles. Their account of how use of these sign vehicles develops draws on the writings of the two Russian scholars, Lev Vygotsky and Gustav Shpet. Building upon those contributions, Wertsch and Kazak observe that when newcomers employ a novel sign vehicle, a new word or a language, they may use it in ways that convey a deeper understanding than they in fact possess or of "saying more than [they] know." They illustrate this by examining how students in the Lehrer/Schauble classroom make use of the graph paper within their design task. Packer (Chapter 10) argues that accounts such as this focusing on mastery of a cultural tool may overlook learners' creative use of such artifacts. He offers an alternative reading of the two fragments analyzed in the Wertsch and Kazak target chapter highlighting the students' "ontological construction." In his commentary, Sherin (Chapter 11) develops a "conceptual change" perspective on the socialization processes described by Wertsch and Kazak. Sherin is concerned with the "intuitive science knowledge" that students bring to the instructional setting and upon which new learning is constructed. He argues that prior understandings may serve as a more significant resource for (and, possibly, impediment to) learning than the Wertsh and Kazak account would suggest. Wegerif (Chapter 12), in his commentary, raises the question, what does the term *dialogic* actually signify? He offers several possibilities drawn from different literatures. He re-examines the classroom illustrations from Wertsch and Kazak's chapter and argues that whatever learning can be found there builds upon a substrate of "dialogic relations within which people can interpret each others' signs and take each others' perspectives" (p. 218). The readings of the excerpts produced by Wertsch and Kazak, on the one hand and by the various commentators on the other, diverge on a variety of issues – learner agency, teacher authority, the goals of the activity, the role of prior knowledge, etc. Derry (Chapter 13) asks, what sense might teachers in training make of these debates and what does it say for the prospects of video-analytic studies of practice, if analysts can take such widely divergent views of the same materials? She suggests that it may be difficult for teachers to appreciate the distinctions being made in these arguments and that recommendations coming from such studies need to be made more concrete in order to be useful to practitioners. Wertsch and Kazak respond to their critics.

The final position paper delivered at the workshop was presented by William Clancey (Chapter 15). Unlike participation/identity theory with its focus on shifting social arrangements or dialogic theory with its orientation to text and voice, Clancey (1993, 1997, 1999) has developed a more biologically-oriented treatment of learning as a form of perceptual and conceptual coordination. In developing this perspective, Clancey draws on diverse sources including: the biologist Maturana (Maturana & Varela, 1987), the psychologists Gibson (1979) and Bartlett (1977), the anthropologist Bateson (1972), and the American pragmatist philosopher John Dewey. In his target chapter, Clancey argues that notions like affordance are frequently misunderstood because stored-description models of memory are biologically incorrect. It was Dewey (1896/1972), in an early article on the "reflex arc concept in psychology," who provided the foundational notion of perception-motor coordinations that was to play a central role in Clancey's theorizing. And it was Dewey (drawing himself on C.S. Peirce) who introduced the concept of "inquiry" (Dewey, 1938/1991) as an experimental (and experiential) way of knowing. Finally, it was in Dewey's later writings with Arthur Bentley (Dewey & Bentley, 1949/1991), that Clancey encountered Dewey's arguments for a "trans-actional approach to inquiry" that provided the basis for what Clancey (1997) terms the "transactional perspective" (p. 175). As noted by Bernstein (1971, p. 211), Deweyan inquiry, when successfully carried out not only effects a change in the problem solver (what psychologists treat as "learning") but also leads to a reconstruction of the problematic situation that led to the inquiry in the first place. The transactional perspective, then, is one that attempts to understand learning as a psychological/biological change in the organism in coordination with ongoing changes to the learner's material and social environment. Over the years there have been several efforts to draw out the educational implications of this theory (e.g., Thomas, 1968; Rosenblatt, 1994; Koschmann, 2001).

Säljö, in his commentary (Chapter 16), raises questions about the strength of the "coupling" between neuropsychological theories and "culturally-relevant" learning in Clancey's target chapter. Säljö also cautions that such forms of theorizing can lead to institutional policies that may be detrimental to learners. In a second commentary, Cobb (Chapter 17), drawing like Clancey on Dewey, argues that theoretical frameworks must be evaluated *"in terms of the insight and understanding they give into learning processes and the means of supporting their realization"* (p. 293, original author's emphasis). He analyzes Clancey's transactional perspective, therefore, in terms of what it might offer for design research. Garrison, a prominent Dewey scholar, seeks to deepen Clancey's "reconstruction" of Deweyan transactionalism. His commentary (Chapter 18) ranges over a variety of topics including motivation in inquiry, sign vehicles and thought, and the "under-determination" of reference. In the final commentary (Chapter 19), Jere Confrey writing from the perspective of a math education designer, examines a bit of instructional dialog (Excerpt 7) not taken up by Clancey or any of the other chapter authors. She focuses on the students' "meta-representational competence," what it is and how it might be fostered in settings like the classroom described here. She concludes that a transactional perspective might be helpful in studying such matters.

The chapters in the concluding section seek to achieve some synthesis across the three sections. They begin with a reflection chapter by Lehrer and Schauble. As designers and educators, Lehrer and Schauble describe the questions and issues that the analyses and discussions have raised for them. Rogers Hall (Chapter 22) takes up the question of how and when a sense of context is developed in a secondary analysis. In endeavors like the current one, in which multiple analysts seek to make grounded observations about materials for which they had no prior familiarity, context might appear to be "mobile." Frederick Erickson (Chapter 23) observes that, "We still understand very little about the phenomenology of video viewing for purposes of systematic analysis" (p. 399). He argues that video is always seen through a lens shaped by one's theoretical orientation and past experience. It is perhaps not surprising, therefore, that there is little apparent convergence in the analyses produced in the various chapters of the book. In the final chapter, Ray McDermott returns to the question that motivated the Allerton workshop, namely, what is the role of theories of learning in the study of instructional practice? He responds with a question of his own, can we afford theories of learning? He warns that theories of learning come with political implications and we must be very careful when we embrace one.

The three formulations of learning presented in this volume are each different with respect to the traditions from which they arose and the critical stances they achieve. Our goal was to bring points of potential disagreement to the surface. In a fashion all too rarely seen in educational research today, scholars from different disciplinary traditions critically engage each others' work, challenging its assumptions and calling its claims into question. Those readers looking for definitive answers to the questions raised in these chapters, however, are likely to go away unsatisfied.

The 2003 workshop was organized to begin a conversation, one that was enriched and extended in the chapters of this book. We now hope to open that conversation to the research community at large.

Notes

1. A slogan frequently attributed to Thorndike is, “All that exists, exists in some amount and can be measured.” Clifford (1984, FN1, p. 283) suggests that this was actually a paraphrase of something Thorndike had once written augmented with a related thought from one of his former students, William McCall. She traces its source to a 1918 report in which Thorndike wrote, “Whatever exists at all exists in some amount. To know it thoroughly involves knowing its quantity as well as its quality.”
2. Thorndike’s approach has the distinction of having been codified into law. It is built into the “scientifically based research standards” of the Education Sciences Reform Act (H.R. 3801) signed into law November 5, 2002 by President George W. Bush.
3. Or, more accurately, fails to engage instructional practice. Practice, in fact, was not something that Thorndike considered to stand in need of study. Clifford (1984) reported that he discouraged his graduate students from wasting their time in classrooms. According to her (1984), “he remained unconvinced that either educational psychology or a scientific pedagogy require[d] this” (p. 231).
4. See the chapters by Macbeth (Chapter 4) and Erickson (Chapter 23) for historical accounts of some of this earlier practice-based work.
5. This is a more rudimentary treatment than that found in other sources. It aligns well with de Certeau’s (1984) usage of the term as simply “the ways in which users – commonly assumed to be passive and guided by established rules – operate” (p. xviii). Others, however, build additional distinctions into their definitions. Barnes (2001), for example, defined practices as “socially recognized forms of activity, done on the basis of what members learn from others, and capable of being done well or badly, correctly or incorrectly” (p. 19). Scribner and Cole (1981) similarly assign a social dimension to practice and associate it with tool use:

   > Whether defined in broad or narrow terms, practice always refers to socially developed and patterned ways of using technology and knowledge to accomplish tasks. Conversely, tasks that individuals engage in constitute a social practice when they are directed to socially recognized goals and make use of a shared technology and knowledge system. (p. 236)

   In certain strands of sociology (see, for example, Schegloff, 1997), a distinction is been made between *practice* and *action* – action being what some observed practice is recognized to do. Such distinctions are skirted here, however. For the purposes of this discussion, the term is used to simply denote that which has been, in the main, systematically eluded and elided within mainstream educational research.
6. Macbeth was writing about conceptual meaning and wrote, “Yet the insight of natural language studies is that language use is conceptual, and is so in the same way that meaning is: The sense of our every expression has worlds attached, and is conceptual in that way” (page 6, footnote 4). The point, however, also holds for how we understand a practice.
7. See the synthesis chapters by Hall (Chapter 22) and Erickson (Chapter 23) for further discussion of comparative analyses.
8. Schegloff, in an interview (Čmejrková, & Prevignano, 2003), observed, “These days, only such work as is grounded in tape (video tape where the parties are visually accessible to one another) or other repeatedly (and intersubjectively) examinable media can be subjected to serious *comparative* and *competitive* analysis” (p. 28, emphasis added). It is a common practice among researchers who study conversation to share the primary materials upon which

they have developed their analyses, making possible the production of "competitive" analyses. This is not an unreasonable way to maintain rigor within a field. (Educational researchers might take note!) In the case of the current book, however, our principle interest was one of clarifying how different theoretical framings might serve to highlight different features of the materials. Hence, the presentation of our project as a "collaborative analysis."

9. It might be mentioned in passing that there is a considerable amount of prior experience, amongst the various chapter authors, with this kind of collaboration. Greeno and Hall, for example, contributed analyses to the *Discourse Processes* special issue on 'meaning making' (Koschmann, 1999). Kay McClain was one of the organizers of another collaborative analysis that appeared in the *Journal of the Learning Sciences* (Sfard & McClain, 2002). Cobb contributed an analysis to that collection and Macbeth was a discussant. Finally, both Erickson and McDermott were involved in Grimshaw's MAP project.
10. In some comparative analyses (e.g., Grimshaw et al. 1994; Koschmann, 1999), the materials made available for shared analysis may be tightly constrained. That was not the case here.

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Chapter 2
Designing to Support Long-Term Growth and Development

Richard Lehrer and Leona Schauble

Our work has a long-term focus on describing and explaining the development of students' disciplinary learning histories. We seek to better understand how and why students enter and become fluent in forms of thinking and knowing that are particular to the scientific and mathematical disciplines. What resources for and barriers to these specialized forms of thinking do young children bring? How can educators best build upon those resources without creating breaks in students' sense making? Specifically, for the past dozen or so years we have been conducting classroom-based research on the origins and development of model-based reasoning in mathematics and science (Lehrer & Schauble, 2005). Like many complex forms of disciplinary thinking, this one does not develop over the short term. Instead, it is probably best conceived as a life-long enterprise, one that the youngest students can enter in some form, but that remains both central and challenging even in the practice of professional scientists. A pressing question for us is how classroom episodes, lessons, months, and years of instruction cumulate in a repertoire of models and a propensity to engage in what Hestenes (1992) calls the "modeling game."

Before readers dive into the chapters to consider this question for themselves, we begin by describing the larger context within which this research was conducted and next move on to explain what we were trying to achieve educationally – both over the long term (i.e., the entire collaborative enterprise) and the relatively short term of this particular study.

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The Context

It goes without saying that the conduct of inquiry about learning in any classroom is negotiated within a larger institutional system that has its own trajectory of interaction and learning. Saxe and Esmonde (2005) have suggested that a comprehensive view of development entails consideration of change at microgenetic, ontogenetic, and sociogenetic levels. Microgenetic change was the focus of the investigation reported here – that is, we were investigating conceptual change and the means to support it in a circumscribed curricular landscape. Because we are concerned with education, we focus on microgenetic arcs that may extend for weeks or months, although of course, one could focus on change at the scale of minutes, or even seconds. The second form of change, ontogenesis, traces trajectories of individual development over a more prolonged period of time. For us, the relevant time scale is measured in years: We worked with teachers to establish threads of teaching around a few core concepts and practices in sciences and mathematics. Together, teams of researcher-teacher colleagues engaged in multiple cycles of design and revision. Teachers worked in cross-grade teams, collecting samples of student work and developing cases of student learning to inform the wider teacher community (see Lehrer & Schauble, 2002 for a sample of teacher work in the data modeling domain featured in this volume). Over time, the work in this teaching community was transformative – a kind of change in the culture of teaching that Saxe and Esmonde (2005) call sociogenetic. Hence, new work, such as the work undertaken in this study, was negotiated in light of both existing and robust teacher practices and also, existing ontogenetic trajectories for the participating students.

Although these forms of change were indeed operating (see Gamoran et al., 2003, for independent documentation), they did not always operate smoothly. As usual in extended school-based work of this kind, there were a number of disruptive influences, including broader macroeconomic trends that were impacting the district. During most of our time there (and continuing today), the district was one of the fastest growing in the state. As a result, some of the participating students were long-term residents of the district, while others were newcomers and therefore were being inducted into classroom practices that were initially unfamiliar to them. These factors were a source of both variability and unanticipated contingency at the classroom level. In addition, as the district grew, so, too, did the need for more teachers. New teachers were constantly coming into the teaching community, and the rapid expansion generated wide variability in classroom practices, despite the fact that teachers endorsed similar curricular goals and tasks. The teacher who participated in the current study was a relative newcomer to the group, although he had worked with us to conduct a design study the previous academic year.

The educational design was longitudinal and purposive in character. We wanted to both identify and build on young students' resources for modeling in mathematics and science (Lehrer & Schauble, 2004, 2006). Moreover, we had a commitment to finding ways to help younger students and novices find easy access into these ideas, but also a corresponding commitment to continually up the ante for students, so that increased challenge and explanatory power were continually being forged. Over the many years of this research, we developed reasonably elaborated notions of what we hoped to accomplish at each grade. The focus was on development, so that at every grade, children's mathematics built on the mathematical ideas that had previously been put in place and also needed to support the modeling approaches to science that we were investigating. Many of these mathematical and scientific ideas are not typically taught to elementary school children at all, but followed from research and our own conceptual analysis of what would best support the long-term development of student disciplinary knowledge. Administrators permitted this latitude in instruction because the statewide test scores in mathematics, especially in the classrooms in which we worked most intensively, continued to show yearly improvement (Lehrer & Schauble, 2004). The superintendent often dropped in during our professional development sessions (we held them in the district's administrative center) and decided on the basis of his observations that much of the improvement in these scores could be attributed to the activity of this professional teaching community. Innovation was further held to account in the metric of accountability via students' performance on yearly state tests. This accountability was important to members of the school board, especially those who ran on a "core knowledge" platform.

What was the new work intended to contribute? In this instance, we were seeking a capstone to ontogenetic trajectories established (in the ideal) for measurement and for data. The measurement trajectory began with fundamental ideas of measure in length, area, and volume during the primary grades and then progressed to include ideas of error and distribution in the later elementary years (Lehrer, 2003). Our rationale was that measurement is an important mathematical system in its own right and moreover, plays a critical role in our approach to modeling. Developing a measure of an aspect of a natural system requires developing a more thorough understanding of it. The work with data focused on developing representational competence and on enhancing intuitions and representations of variability (see Lehrer & Schauble, 2002, for descriptions of work with teachers to support their ability to teach along this trajectory). Instead of skimming over a wide variety of science topics at the surface level, our students were building deep and cumulative knowledge within bounded domains by posing questions, developing measures, and building, testing, revising, and critiquing models of the natural world.

The Educational Design

Although learning cannot be considered an instance of kinematics, except in the hearts of the most die-hard epistemic realist, nonetheless, images of trajectory are useful for anticipating the scope and sequence of instruction. We had in mind an end-point where students would be able to represent natural variability with the mathematics of distribution and chance, and to employ this emerging capacity to envision growth in a new way – as change in populations. Our hope was that this more complex sense of growth would complement their resources, developed in earlier grades, for representing change in individual organisms as rates of growth. In other words, we sought to provide mathematical resources that would make it possible for students to make the difficult shift from thinking about organisms to population thinking. With that overall goal in mind, we envisioned five phases of instruction.

First Phase: Purposes and Measures

In all investigations, we aimed to underscore the tight relations between the questions that students posed about a natural system and the attributes and measures that could be generated as data in service of these questions. In this investigation, the teacher engaged the group in the generation of questions that focused on the effects of different amounts of light and fertilizer on the growth of plants (these were Wisconsin Fast Plants®, which grow in 40 days and thus are well suited for classroom investigations). Students predicted that both light and fertilizer would make the plants grow taller and perhaps affect other measures, such as their "width," as well. Collectively, students designed experiments with contrasting conditions, regarding height as the most prominent of the dependent measures. They recorded these measures (along with others) as the plants grew.

A second goal of the initial phase of instruction was to engage students in reasoning about the means and methods of measure: What is meant by "height?" "Should the height of the plant include the roots? Suppose the plant leans as it grows or develops multiple branches?" What is a good unit of measure? Thinking through and achieving consensus on these questions helped students appreciate the interpretation of their measures and consider the degree of trust that they had in them. For some students in the room, this was a familiar kind of argument, but for relative newcomers to the classrooms of participating teachers, it was not. After resolving these issues, students recorded heights of plants grown under different conditions throughout their life cycle, keeping data in the form of simple records of their own design. We made no effort to impose any particular structure on the measurements. Students also developed methods of measure for other attributes (e.g., width, number of leaves, seedpods), but we settled on height for introducing concepts of distribution, the focus of the second phase of instruction, because it seemed most prominent to the students.

Second Phase: From Difference to Structure

In this portion of the instruction we intended to support a transition from students viewing the collection of plant heights on any particular day of growth as merely different, toward apprehending a structure (a distribution) regulating these differences. Students were keenly aware of natural variation, that is, that the collection of plants was not of a uniform height at any point in the life cycle. We asked students to design displays that would illustrate a "typical" height and spread of the plant heights at a single day (the 19th day of growth), and as we describe below, these are the segments on which the Allerton participants devoted most of their focus. We hoped to contrast case-based views with aggregate views of the same data, so that students could come to see the “shape of the data” as reflecting choices about what to represent in the data, and how. diSessa (2004) refers to this sense of appreciation of the consequences and implications of different choices of data display as meta-representational competence. The inherent tension in the design was that students had never considered viewing plants collectively, and so for them, the value of this form of analysis was not transparent. Yet many of the students in this class had generated distributions of repeated measures during the previous year (Petrosino, Lehrer, & Schauble, 2003), and so we conjectured that these earlier experiences would serve as resources for the current enterprise. We have since learned that considering variability as produced by random error or by some other “natural” random process raises very different challenges and affordances (Lehrer & Schauble, 2007; Konold & Lehrer, 2008).

Students worked in small groups to create their displays. During this small group activity we wanted to elicit students’ thinking and to promote, in at least one or two groups, displays that would treat the data as aggregated, rather than as a mere collection of discrete cases. In other words, we hoped to provide opportunities for students to develop a firmer coordination between their knowledge of and natural focus on individual cases (my plant and its unique qualities), with a sense of the aggregate, or the data itself as an object of attention (Lehrer & Romberg, 1996). After completing their display, each group handed it off to another group who were asked, in turn, to interpret what the authors were trying to communicate and to evaluate their success at showing “typicality” and “spread.” This activity structure, which we tend to use repeatedly, creates a sense of audience for the students’ work and thus highlights the communication demands of data displays. It also prompts conversation about design trade-offs, that is, how a particular data display highlights some features of the data and suppresses others (children refer to this as “showing” and “hiding” features of the data). These critique sessions often provide a strong press toward revision and ultimately, toward identifying effective ways of solving representational problems that eventually come to be accepted as classroom conventions (Lehrer & Schauble, 1994). The initial or invention phase provokes a great deal of variability, which is then pruned during interpretation and critique sessions, eventually resulting in agreed-upon solutions to representational problems. We hoped that there would be sufficient variability in the displays to make conversation about similarities and differences mathematically productive. For us, mathematically productive meant coming to see how the design of a display resulted in the ensuing shape of the data, and also, how “hills,” “holes,” and related features notable in a frequency graph result from the interplay between counts of cases and how one defines the corresponding interval. This knowledge is a precursor to the more conventional construct of the density of a distribution. As students began to think about aggregate, we aimed to tie this aggregate to the mathematically important idea of data generated by a repeated process, by asking students what would happen to the aggregate “if we grew them again.”

This task was repeated in a modified form for other days of the plants’ life cycle. Again, we explicitly focused on how choices made by designers influenced the shape of the data display. Which senses of shape afforded easy comparisons of the same sample at different points in the life cycle? One strategy we employed was to build on students' emerging, idiosyncratic partitions of the data (e.g., thirds of the distribution). We felt that student talk about "regions" of the data showed that they were in the process of making the transition from an emphasis on collections of individual cases to aggregate structure (an example of this kind of conversation is included in one of the analyzed video clips). We used these divisions of the data, proposed by students, as a path for introducing conventional divisions, especially quartiles. Students referred to the dividers as "hinges" and the width of the quartiles as "doors." Our goal was to relate changes in the shape of the distribution to conventional representations, such as the box plot. For example, when the distribution of plants became more "normal," students noticed that the middle doors "shrank," and we asked them to account for this shrinkage by relating it to the shape of the distribution of the data (expressed by relative frequencies).

Third Phase: Coming to See the Sample as Varying

As students worked on ways to structure variation as distribution, their teacher again asked them to consider what would happen if they grew the plants again, but this time tying the image of repeated process more explicitly to chance. The aim was to invoke an image of a (random) repeated process, with a sampling distribution as a way of characterizing the likely outcomes of these repetitions. Students initially explored this question with random sub-samples of their classroom data (in effect, treating it as a population). They placed cards containing the heights of their plants in large envelopes and drew random samples, pasting the results of their sampling as frequency displays on the walls of the classroom. These displays made sample-to-sample variability quite visible, and the students readily attributed this variability to chance. Sampling without replacement was motivated by our conversations with Patrick Thompson (2000, February, personal communication), who proposed that students tend to conceive of samples as parts of populations. We therefore conjectured that students would find it sensible to literally construct parts (samples) and then to examine their relationships to the whole.

We next stretched the metaphor further by introducing sampling with replacement as a model for "growing again." Using a computer program developed by Andrea diSessa (a prototype written in the Boxer programming environment), we varied the sample size and number of samples employed to look at the shapes of the resulting distributions of statistics (means, medians). Selection of these statistics was motivated by employing them as ways of representing the tendency observed by students for the "middle" to be recovered from sample to sample (The notion of "middle" was an interesting opportunity to contrast the probabilities of recovery of any single case being sampled, that is, 1/n, to that of the event class defined by the center clump or by other regions of the data – see Lehrer & Schauble, 2004). The computer tool aggregated the results of the simulation into ordered intervals and plotted them as histograms. During these sampling experiments students generated explanations of what they were seeing and tested their explanations by conducting additional investigations. For example, some students proposed that small samples of 2, compared to larger samples, would increase the sampling variability of the mean or median, because “bad luck” might easily lead to including an extreme value that would skew the results away from the center clump.

Fourth Phase: Distributions as Signatures of Growth Processes

We next sought to repurpose these concepts about distribution and chance to a new question: How did the distribution of the plant heights change over time, and what might account for this change? The goal was to promote distributions as signatures of growth processes (Gould, 1996). When growth processes change, so, too, do distributions of the population of plants.

Fifth Phase: Reconsidering Experiment

In the final phase students revisited their initial conjectures about the effects of light and fertilizer against the background of their emerging understanding of distribution and sampling. They contrasted samples of plants grown under conditions of low light or high fertilizer to a larger sample of plants grown under standard conditions. We reminded students about “growing again” to connect these contrasts to images of repetition and thus inference about effect to sampling (e.g., what might be expected if we grew them again vs. what had happened under known conditions of light and fertilizer). We knew that students’ conjectures about the effects of fertilizer would not be supported by these data – counter to their expectations, Fast Plants do not grow taller if they are given extra fertilizer, although their canopies grow wider. Because we knew that the data would disconfirm a favored theory, we anticipated that this context would be especially productive of data based argument. We were aware of the literature about preadolescents’ tendencies to base their arguments primarily on beliefs about the way the world is (Kuhn, 1989) and felt that if students were asked to reason about data that clearly did *not* support their favored beliefs, they would be more likely to engage beliefs and evidence as separable dimensions of consideration. Essentially, we asked students to invent a method of comparison that would work to resolve differences about the prospective effects of light and fertilizer. Our intention was to ground inference in sampling variability, but to do so without the mechanisms of formal inference, such as the confidence interval.

The Classroom Data

The video segments on which this book is based represent our very first attempts to help students think about natural variation of populations (in this case, of plants) via deep understanding of seminal ideas about distribution. Consistent with our interest in cumulating knowledge within domains across grades, this was not the first investigation of plants that these students had undertaken. As first graders they had grown flowering bulbs of various species and had investigated changes in the heights of the bulbs over their lifecycles. These investigations served as a context for students to employ their developing understanding of measurement. In the third grade, students studied changing rates of growth by constructing piecewise linear graphs of the heights of individual plants. In response to a teacher's challenge to find a way to "draw one line that shows how all our plants grew together," they proposed a line that connected the midrange of the distributions of plant heights at each day of measure. They then held an extended debate about whether this solution was legitimate. Because the line intersected some points that represented the height of none of the class's plants, the argument focused on how a value could be considered typical if it did not include any of the cases being described. Next students constructed rectangular pyramids and cylinders out of paper to test a conjecture about the changes in the volumes of the plant canopies. With mild disappointment, students noted that their conjecture (that the volumes of the plants would increase in constant proportion) was not correct, but we were impressed with both the question and the models proposed to test it. In the fourth grade, students grew plants in "crowded" and "uncrowded" conditions and compared the resulting distributions of height by eye to determine whether there were discernible differences in plant height, width, volume, number of leaves, and seedpods as a result of these two conditions of growth. The lessons analyzed in the workshop focused on our initial attempts, working with a collaborating fifth-grade teacher, MR, to develop the underlying conceptual understanding of distribution that could appropriately guide inferences of this kind.

Therefore, the video sent to the analysts represents our first attempt to work out these ideas in a classroom. Although we had, of course, a general idea of where we wanted to go, the details were being manufactured in the process, and every day was capped with a meeting between the research team and the classroom teacher to retune or revise our plans in progress. Those who consult the transcript will note that the chapter authors were in the classroom each day along with Christopher Hartmann, a research assistant (we have included below a brief summary of each of the video clips referenced by the chapter authors, along with our own abbreviated comments about these events). In addition to planning next instructional steps, our role in the classroom was to document student conversation and learning and to talk with small table groups of children as they solved problems and conducted investigations. Given the developmental status of this work, we acknowledge openly that the teaching in this segment is often shaky, sometimes even clumsy. Subsequently there have been many replications with (considerable) revision of this introduction to variability, and students in Wisconsin, Arizona, and Nashville have participated in iterations of the instruction. We would not want readers to assume that we are claiming this material as an example of excellent practice. Instead, in this piece, students, teacher, and researchers alike are struggling to create an innovation, to understand relations between teaching and learning, and to characterize what seems robust about each. Many mistakes of many kinds were made along the way. The discerning reader will readily perceive that he or she is witnessing an instructional design in the making, which may be part of what makes these data interesting.

Transcripts for the twelve video clips analyzed during the Allerton workshop can be found in Appendix B in the back of this volume. (The transcription conventions are described in Appendix A.) The events captured in these excerpts occurred during the second phase of the instructional unit described earlier. The video was collected in a fifth-grade classroom in which students discussed plant growth and development and then grew Wisconsin Fast Plants® under different conditions of light and fertilizer. The data described in the video excerpts were collected on the 19th day of plant growth, or approximately halfway through the plants' life cycle. The video excerpts open on the 26th day following the planting of the seeds, with students being asked to design representations of the data they had collected from their plants. At that point, students were still engaged in the process of collecting data, but were structuring data already recorded. On the next day of instruction (Day 27 of the plants' growth), students exchanged representations and began making whole-class presentations, which continued into the following day (Day 28 of plant growth).[1]

Excerpt 1: Introduction of a Data Representation Challenge (Day 26)

MR introduced the task that students will be working on over the next few days. Students were asked to invent and compare data displays, considering what different displays reveal and hide. This emphasis on representation is a hallmark of the program that RL and LS are introducing in the school. The students' measurements have been collected. The values are presented on a flip chart (see Figs. 2.1 and 4.1).

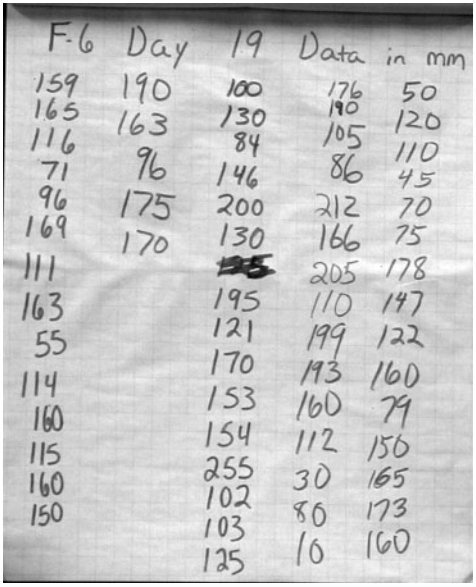

Fig. 2.1 The converted Wisconsin Fast Plants® height measurements from Day 19

The task, which will be carried out in "table groups" (semi-permanent, small groups of students who sit together at a table), is to find a way to represent the data so that the display shows the typical height of a Fast Plant at Day 19 of growth and also, how spread out the data are (see Fig. 22.3). MR says, "If you could answer these questions by the end of today, you've done pretty well" [0:02:10].

Excerpt 2: Getting Started (Day 26)

Group 1 begins their design process. RL has agreed to serve as "recorder" for the group. Caleb, Kent, and Garett have an extended exchange about where to start plotting their data. Should they begin the chart at 30 mm, the shortest plant, or at 0 (see Fig. 15.4)? Kent complains, "It's just all kind of weird starting from 30" [0:09:09]. Caleb agrees, "It doesn't make any sense to start at zero number when they're not even up there" (i.e., there is no plant that is 0 mm tall).

Excerpt 3: How Should We Look? (Day 26)

Group 2 begins to design their representation without direct adult input (see Fig. 12.4). The students sit in a circle around a small table. On the table is a large, single sheet of oversized graph paper on which they are to produce their design. A focus of the discussion appears to be how to fit all the measurements onto the piece of paper, whether they should be listed along the short side or the long side of the piece of paper, and whether the numbers will fit if the graph is scaled so that one square accounts for 3, 5, or 10 of the values. One obstacle to the collaborative design work is that, given their positions at the table, only one student has a view of the worksheet as it will be seen when the design is complete. The others must rotate or invert their views to align with the view of the person sitting on the side of the table closest to the bottom of the graph. This leads to differences in opinion about what will serve as the top/bottom, right/left of the designed representation. Different proposals are warranted by appeal to what will fit on the sheet, what will be neat, and how one conventionally constructs a graph, etc. Students attempt to reconcile the proposals by inviting one member (Jewel) to move to the position of another (Wally) in order to better understand his position. The topics of "typicality" and "spreadoutness" are never taken up explicitly.

Excerpt 4: An Adult "Assists" (Day 26)

This excerpt captures Group 3 designing their representation with the assistance of LS (see Figs. 10.1, 10.2, and 12.3). As in Excerpt 3, much of the discussion focuses on finding a way to fit the data from the flip chart onto the provided piece of paper.

Again, this entails disputes about out how to order the values, lots of counting, and some negotiation with respect to the nature of the task at hand. For example, Jasmine counts the number of squares across the side (35) and bottom (22) of the paper and then multiplies them, presumably with the intent of putting one value into each square. Later, she proposes, "…we could just show the odd numbers, maybe." Interestingly, the problem of orienting the graph on the paper that proved to be contentious in Group 2's design work does not arise as a problem here. In her pointing and counting activities, LS implicitly adopts an orientation for the emerging representation and the students accept this without question. Again, the topics of "typicality" and "spreadoutness" are not taken up explicitly. The students are told to "use their sense" and to think about "what it is that we want to show." "Frequency (charts)" are referenced by LS in the context of displaying frequency in a range. To our taste, this is one of the examples of clumsy teaching that we mentioned above. LS is being far too directive here, but her explicitness is provoked by the goal of ensuring that at least one group will create a display that shows the shape of the data when relative frequencies are represented. In subsequent iterations, we have learned that we do not need to be this explicit – this aspect of the instructional design (inventing and comparing displays) is sufficiently robust.

Excerpt 5: Group 2 Explains Their Progress (Day 26)

Group 2 discusses their partially completed graph, described earlier in Excerpt 3, with RL (see Figs. 4.2 and 12.5). Rich says, "I'm not sure I understand the graph that you made." Plant heights are displayed on the left (from Jewel's perspective), and across the bottom are 63 elements representing the ordinal position of each data value in the table. Anneke points out that there is no need to label the plant numbers across the bottom of the graph (Plant 1, Plant 2, etc.), as April wishes to do. "Well, it doesn't matter. 'Cause you know there's a plant there." RL asks how the emerging graph answers their question (see Fig. 22.4). April's reply suggests that she is not concerned with answering MR's two questions, but rather, with making something that meets her criteria for a graph: "But…but that's the way a line graph normally is." RL asks, "Did anyone say it has to be a line graph?" He leaves the group for a moment, saying, "Well you gotta kinda figure out what you're tryin' to figure out" [0:41:44]. He returns a few minutes later and comments, "What I think you did very nicely here was create some way of arranging your information from smallest to largest. That's a good start. Now you have to think about how you're gonna show each of the values." At this point Wally interrupts to say that he would prefer to work on a "stem-and-leaf" graph (see Fig. 2.2). Rich suggests that the group split, with Wally pursuing his plan and the girls pursuing theirs. MR later (and not transcribed) visits the table. Jewel asks if making a stem-and-leaf graph would count as "organizing the data."

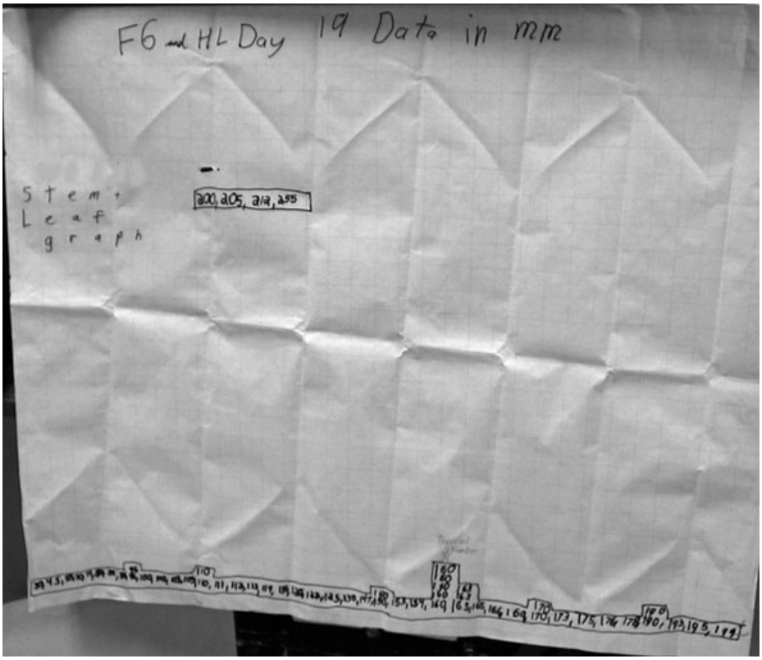

Fig. 2.2 "Stem-and-leaf" display constructed by a student who disagreed with the case-value consensus of his group (Group 2)

Excerpt 6: Group 5 Describes Their Approach to the Task to RL (Day 26)

Janet, Rene, Malcolm, and Kurt (Group 5) are tentatively recording their first data point on their chart (see Fig. 10.3). RL asks them, "Do you need two dimensions to show how spread out they are, or could you do it with one?" Janet replies that one of the axes is needed to record each of the plants ("in alphabetical order") and the other to record the values of the plant heights. RL tries in vain to cue their memory of frequency graphs by reminding them of the data displays they had created the year before, when they displayed the heights of rocket launches. "Suppose the data were not about plant heights, but they were how high the rocket went?" Janet replies, "You'd still use it to show the different heights the rockets *went*." She continues, "And this would be the first rocket, because it's important to see which one it was." RL responds gently, "Well, the rockets were all sent up at the same time, right?" (The reference by RL is to a repeated measure context the earlier year in which multiple individuals measured the height at apogee of a single rocket.)

Excerpt 7: Suppose We Grew the Plants Again? (Day 27)

MR has passed out all the displays so that each table group is holding a display authored by one of the other groups. He has explained that each table group will be

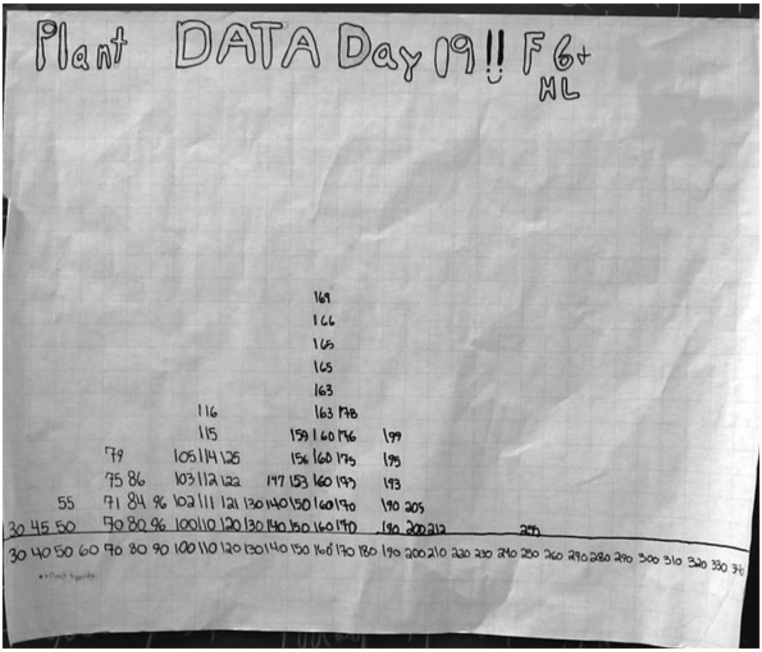

Fig. 2.3 Graph produced by April, Jewel and Anneke (Group 2) on Day 26 (Excerpts 3 and 5)

asked to orally present the display of another, interpreting what the display shows and commenting both on strengths and weaknesses of the display. Group 3 (Tyler, Edith, Kendall, and Jasmine) is attempting to make sense of the graph developed by April, Anneke, and Jewel (see Fig. 2.3). Edith notes that this graph is very similar to the one that they made, so "I don't think they need to change anything at all." CH, a research assistant on the project, asks what would be likely to happen if we planted another 63 plants. Edith notes that in the original data, 11 out of 20 plants fell in the 160–169 mm range, and Kendall says that he would expect to get "somewhere around that number. It could be more, it could be less." CH asks how many plants they would expect to observe from 160 to 169 mm if they planted only 20 plants the next time around, instead of the original 63. Kendall suggests dividing 11 by 63 to find the percentage of the original distribution in that range. Tyler calculates that this would be 17.4% and remarks that "...It's the biggest amount that we will get for any of 'em" (i.e., the 160–169 bin holds the largest percentage of the plants). Part of this exchange can be seen in Fig. 22.5. CH asks, "So does that help you talk about what the typical height would be?" We consider this discussion significant, as it demonstrates students thinking about relationships between regions of the data and the entire batch. They apparently grasp that if they "grew the plants again," the structure of the original distribution would be a good source for deciding what to expect in the new distribution of plants. This is a frequentist view of chance that we value, because it emphasizes the role of repeated process in the interpretation of chance.

Excerpt 8: Grouping or "Binning" the Data (Day 27)

This is one of the whole group presentations. Rene and Janet from Group 5 present the graph designed by Group 1. The Group 1 graph is simply a list of the values, in order, across the bottom of the paper. Students apparently ran out of room and simply inserted the remaining values further up on the page. The exchange involves a misreading by Janet of Group 1's computed mean value. Next Anneke, Jewel, and April discuss the graph designed by Group 3. MR asks students to compare the ways that the different displays group the data. He introduces the term "bin" as a special word that refers to these groups of data. We considered it critical for students to grasp the notion that data could be grouped this way, and further, to understand that changing the bin size changes the shape of the distribution. "Shape of the distribution" will be a central theme in the instruction that follows over the next several weeks. Students eventually come to understand that the shape of the data supports interpretation, and moreover, that the data representing plant heights changes its shape in a predictable manner over the life cycle of the population of plants.

Excerpt 9: Showing Spread of the Data (Day 28)

Group 1 is at the board (see Fig. 19.3) presenting a representation made by Group 5. Actually, Group 5 made two. Rene and Janet produced the display shown in Fig. 2.4 and Kurt and Malcom made the graph shown in Fig. 2.6. Rene and Janet's display is not a graph, but rather, a list of all the plants heights in order, starting from the top left of the paper and continuing to the lower right. Just before the fragment begins, Garett, who is at the board presenting their representation, is critical of how the girls made their "graph." He argues that his own display (not shown), which lists the values in order across the bottom of the page, does a better job of showing "spread-outness." He points out that Rene and Janet's display uses up the entire page and does not emphasize the length of the string of values from beginning to end, because it continues over several lines. Rene and Janet rise to the defense of their representation and explain that it is better than Group 1's graph (which they presented earlier), because they included an annotation indicating their answers for typicality and spread. Garrett and Kent retort that these qualities were to have been made visible in the representation itself, and without the annotation they would be "clueless."

From our perspective, neither of these displays is going to reveal the shape of the data. MR, therefore, proposes a thought experiment – what if the highest value were 555, instead of 255 (Fig. 15.3)? Which of the graphs on the board would best show this change in spread? Kerri eventually comes to the board and identifies Group 3's graph, a frequency distribution (see Fig. 2.5). "Well," she says, "I think that probably this graph, because they still leave some spaces there.... you can really see how spread out it is...and you can see ...how much space is there between it" [0:12:48]. Ian adds, "It's not just the numbers that we actually measured that are in between, but *all* of the numbers" [0:13:41]. It is common for students to omit bins

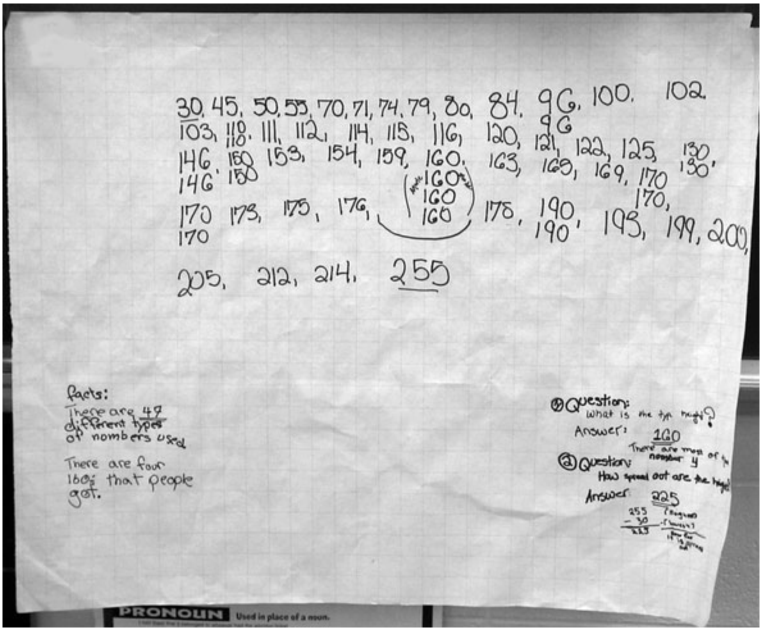

Fig. 2.4 Rene and Janet's (Group 5) tabular representation of the data produced on Day 26 (Excerpt 9)

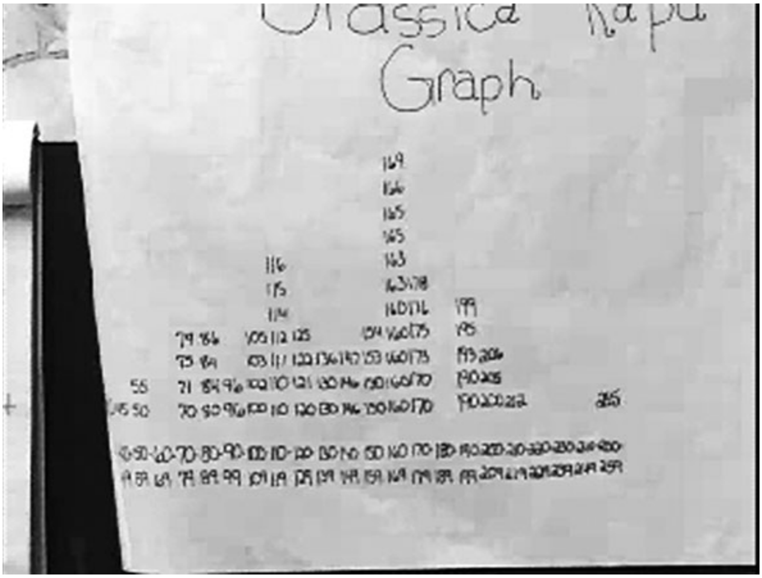

Fig. 2.5 The 10-bin graph produced by Group 3 (Tyler, Edith, Kendall and Jasmine) on Day 26 (Excerpt 4) and discussed on Day 28 (Excerpts 9 and 12)

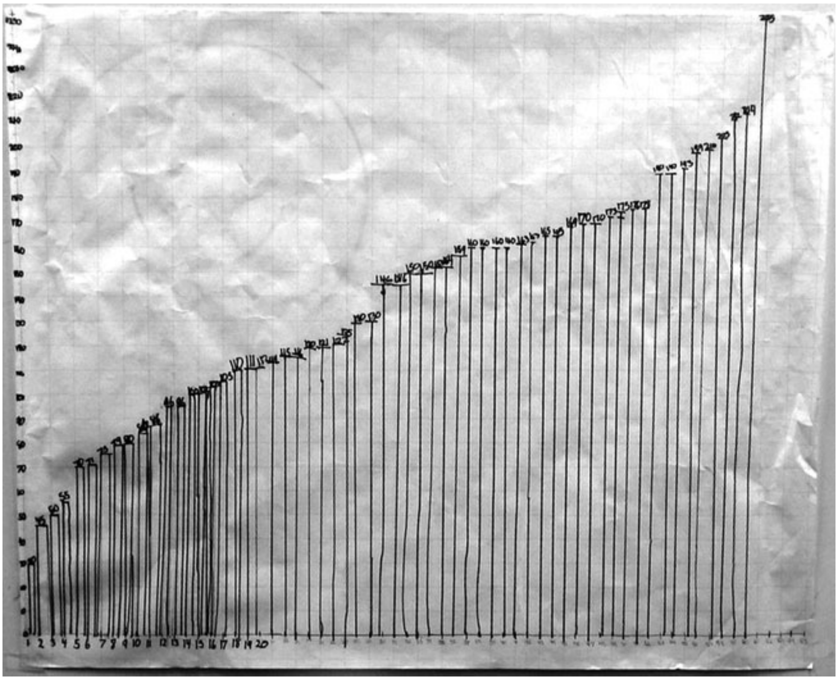

Fig. 2.6 Kurt and Malcolm's (Group 5) graph discussed in Excerpt 9 that introduces the notion of scale

that have no observed values. Doing so hides the "holes" in the data and provides a misleading picture of the "spread."

Excerpt 10: What Is a Good Representation? (Day 28)

In this Excerpt we see a contest between two different criteria for what counts as an admirable representation. On the one hand, students are impressed by solutions that are clever or original, even if they are arcane. Competing with this value is MR's continued insistence that the display should allow readers to easily interpret typicality and spread. Ian, Kerri, and Cindy (Group 4) present a graph developed by Group 6 (Fig. 2.7). This rather unusual graph orders the hundreds and tens places along the Y axis (13, 14, 15, etc.) and the ones places along the X axis (1, 2, 3, etc.). So, to identify 157, for example, one would locate the 15 on the Y axis and move over 7 on the X axis. Ian begins his description of this graph by commenting, "It's a little bit confusing." MR asks, "What about it helps you see that the numbers are spread and what a typical plant would be?" When they are asked to point to a "typical" fast plant, Ian and Kerri produce a series of points and gestures. Dispute ensues in which they take different positions with respect to how "typicality could

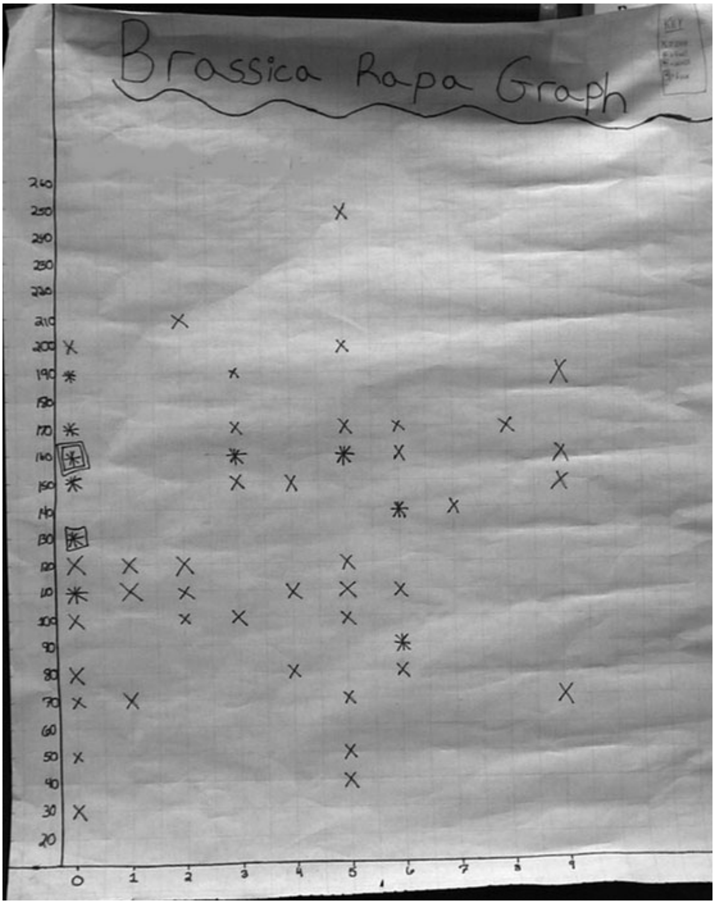

Fig. 2.7 Group 6's (Michael, Debbie, Kay and Jacki) graph of the Wisconsin Fast Plants® height data presented to the class by Group 4 (Ian, Kerri and Cindy) on Day 28 (Excerpt 10)

be read off this representation." Kerri explains how the graph is intended to be read, and the class is clearly impressed. Erica remarks, "You guys are so cool!" MR asks Erica, "What makes it easy to see what's typical?" Erica admits, "It's kind of hard to see that."

Excerpt 11: Another Clever (But Opaque) Solution (Day 28)

Group 6 shares a graph designed by Group 4, Ian, Cindy, and Kerri. This graph, like Group 6's, is a design extravaganza. It displays the median of the distribution at the top middle of the page, poised on a set of carefully drawn stairs. Other values descend from the median on the stairs, although it is not clear that the display

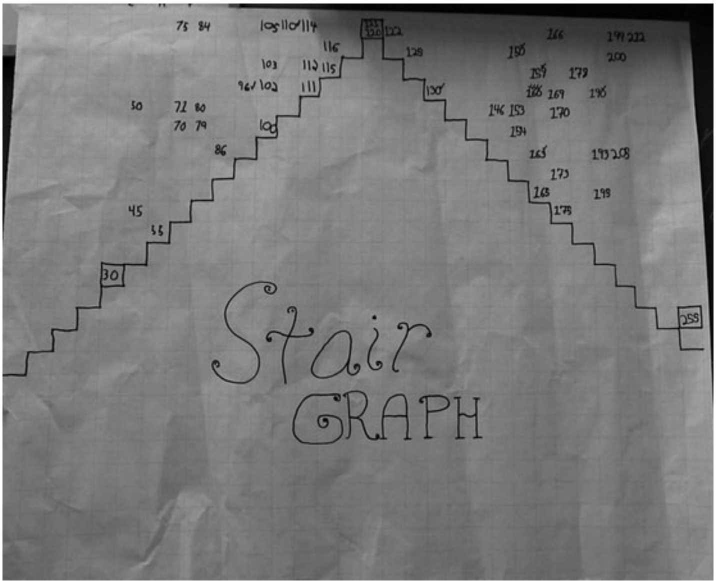

Fig. 2.8 The "stair graph" produced by Group 4 (Ian, Kerri and Cindy) and presented by Group 6 (Michael, Debbie, Kay, Jacki) on Day 28 (Excerpt 11)

preserves interval (see Fig. 2.8). Kerri is asked by another student about her source of inspiration for this design. She replies, "We were thinking about different graphs that we could make," confirming our impression that she was focusing on originality of design, rather than how well the graph showed typicality and spread. One of the students remarks, "I don't think I've ever seen one like that before." Another student points out, "This one is kind of hard to read. When you first look at it, you think, 'What the heck did you do?'"

Excerpt 12: A "Typical Region" of the Graph (Day 28)

Group 3 (Tyler, Edith, Kendell, and Jasmine) present the graph designed by Group 2 (April, Jewel, and Anneke).[2] Note that they had "shared" the graph produced by Group 3 on the previous day [Day 27: 0:26:00–0:30:55]. Tyler begins by pointing out that Group 2's graph (see Fig. 2.3) looks very much like the frequency graph that his group had created: "This is a bin graph. This basically was the exact same as ours" (see Fig. 2.5). Kendall recounts how, in their earlier conversation with CH, they had concluded that a typical plant was most likely one whose height fell in the highest column on the graph (see Fig. 22.6). He adds, "…and we found the percent. It was about 17 point something." MR asks for clarification: "Are you saying 17% of all the numbers fall in here?" Kendall went on to explain that they did not think that 17% of the data was a sufficiently large region to feel confident that they had captured the typical value. This concern was probably sparked from his earlier conversation with CH about what values they would be most likely to see once again if they grew another set of plants. Kendall explained that Group 2 therefore added to their consideration the columns immediately surrounding the highest column of values. “So then we tried adding all these, then we get 22 numbers there. Then we got 34%, and we sort of thought that was more like. . .” Tyler finished his thought: “So out of these 3 (columns) were the typical area.” MR re-voiced, “You’re saying that same thing, 34% of the Fast Plants fall somewhere in this area? So you’re saying if you grow a Fast Plant, would you say, Kendall, chances are good that it would be between 150 and 170 because that’s where 30% of all the stuff was?” Then MR pointed to the outlier plant that grew to 255 mm and asked, “What about this one? What’s the odds of your Fast Plants growing 255 mm? Would you say that’s pretty good?” Tyler replied, “I would say it’s one out of 63. . . That’s 1.5%.” This discussion reconfirmed our belief that the students were starting to develop a sense of the shape and regions of the data. The distinction between case (1 out of 63) and aggregate (34%) and the ability to coordinate these two perspectives is something we value from a disciplinary perspective. Moreover, students were beginning to explore chance as embedded in repeated process (the notion of “growing again”), which we later focused on explicitly with a series of sampling experiments.

Coda

The previous description is quite detailed. We provide this level of specificity because we want readers to understand that we had a very particular set of goals in mind, goals that built cumulatively and systematically on the conceptual achievements that students had made in earlier grades. Our interest was not generally in whether children would find something to do with the data, or even if they would find something sensible to do. For our purposes, we were interested in constructing a pathway for moving toward these ideas of distribution. As we pursue educational designs we attempt to walk a fine line between educational romanticism and over-prescriptiveness. Children, of course, are endlessly inventive and have an impressive ability to make sense of situations, but carefully orchestrated assistance must be marshaled to keep those resources developing along ways that are valued in the disciplines. It is equally important that a teacher’s (or researcher’s) ambitions for students’ disciplinary knowledge and reasoning not over-ride or outstrip the ways of thinking and the sense-making that students bring to tasks and situations. In short, our purposes in this work were explicitly educative. We wanted students to encounter and consider a particular sequence of ordered ideas, even though at all times we were prepared to take detours or even to reroute the path based on what we were learning. As instruction progressed, our detours were more frequent. For example, although we initially intended to emphasize sample-to-sample variability, students’ use of the tool developed by diSessa prompted more in-depth excursions into sampling distributions of statistics (e.g., the median of a population) with varying sample sizes from different instances of “doing it again,” ranging from comparatively few repetitions to many. We emphasize this readiness to take conceptual detours, because we believe that our sense of developmental progression is more emergent and contingent than might be suggested by our earlier description.

Notes

1. See Table 23.1 for a concise summary of where each of these excerpts were referenced within the chapters. The excerpts come from three consecutive days at the beginning of a section within an extended unit in which we were just developing the concepts of distribution and chance.
2. Wally, the fourth member of Group 2, presented separately.

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Part II
The Situated Action Perspective

Chapter 3
A Situative Perspective on Cognition and Learning in Interaction

James G. Greeno

My goal in this paper, and generally in my research, is to contribute to the development of a theory of cognition and learning in interaction. The ideal result of this would be a theory that explains dynamic aspects of interpersonal interaction with the same degree of rigor and specificity that are achieved by sociolinguistic accounts, and explains the informational contents of interactions with the same degree of rigor and specificity of information-processing accounts.

[1] An effort to develop integration between these two lines of research has been under way for about a decade. The general strategy is to observe and analyze activity involving understanding, reasoning, and learning by groups of people. Different investigators are approaching this in different ways. Some are taking cognitive theory as the basis and extending the analyses of cognitive processes by including interactions between individuals. These include studies by investigators such as Dunbar (1995), Okada and Simon (1997), and Schwartz (1995). Other investigators are taking interactional theories of activity as the basis and incorporating analyses of information structures in analyses of interaction. I have been working with the second of these approaches,[2] as have many others, such as Goodwin (1995), Hutchins (1995), and Ochs, Jacoby, and Gonzalez (1996).[3]

Analyses of cognition in activity differ in their levels of aggregation in two ways. One difference is in whether the analysis focuses on individual information processing, treating interaction with other people and resources in the environment as a context, or focuses on processes of an activity system composed of the several individuals present (if there are more than one) along with their material and informational resources. The other difference in aggregation involves the complexity and time scale of the activity that is analyzed.

Table 3.1 presents a sketch of some research topics in a matrix of these two ways of varying levels of aggregation. The left column mentions kinds of cognitive phenomena that are studied in research on cognition, learning, and cognitive development. These vary in their levels of aggregation involving complexity and

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Table 3.1 Four levels of analysis of cognition in activity

Achievements to be explained	Analysis from cognitive science and psychology	Situative analysis
(4) Conceptual growth, commitment to learning goals, sustained, persistent participation in learnin practices	• Cognitive development, conceptual change • Academic self-esteem, general motivational traits, motivation in subject-matter domains • Ways of knowing	• Changes in discourse practice; legitimate peripheral participation • Intellective identities regarding learning, academic learning, and learning in specific school subjects; positional identities in school and classrooms with mutual engagement and productive agency in relation to a community's joint enterprise of learning
(3) Adopting tasks, expending effort toward accomplishing goals	• Understanding task instructions • Task-level motivation	• Practices that encourage problematizing and resolving and that position students in disciplinary discourse with competence, authority, and accountability in participation structures
(2) Emergent understanding	• Generative (e.g., analogical) reasoning, heterogeneous representations • Flexibility in thinking	• Negotiating different interpretations for mutual understanding • Problematizing, resolving, and positioning in interaction • Explaining
(1) Routine comprehension, conceptual understanding, problem solving, including performing procedures, search in problem spaces, reasoning, planning, skill acquisition	• Information-processing operations • Search heuristics, schemata, strategies • Acquiring components of procedures	• Conversational contributions, mutual attention, understanding propositions and reference • Conceptual common ground, patterns of reasoning in practice • Shared repertoire of schemata and procedures

time scales. The second column mentions theoretical concepts in cognitive science and psychology that provide interpretations and explanations of findings at the various levels. The third column mentions explanatory and interpretive concepts in the situative perspective at the corresponding levels of complexity and time scale. The cognitive-scientific and psychological concepts refer to processes that are usually hypothesized to occur at the level of individual information processing, thinking, and learning. The situative concepts refer to processes that are hypothesized to occur at the level of activity systems and joint participation in communities of practice.

The strategy for integrating these two lines of research that I find promising involves considering information processing as an aspect of interaction in activity systems. Standard cognitive-science analyses hypothesize that structures of information are constructed by individuals as they understand and reason about situations they are in and solve problems. The processes that generate these structures use other, general structures that are hypothesized to be retrieved from memory. Motivations to engage in tasks and to participate in practices are hypothesized as differential traits of individuals. In the theoretical accounts that I call situative, information is assumed to be constructed in the interactive processes of activity systems. More general structures of information, including practices of discourse and problem-solving strategy, are hypothesized to be in the common ground of participants in activity. And differences between individuals in their engagement in tasks and commitments to practices are considered as different ways in which individuals are positioned in their participation.

In an early draft of his commentary, Bredo (Chapter 6) suggested that my analysis focuses primarily on "an integration of 'task' and 'social' aspects of interaction" (cf., pp. 116–117). I believe that he is basically correct in this.[4] I hope that the analyses I review and present here are contributing to a more integrated theory that includes accounts of information structures that are the contents of interaction and the interactional processes in which those structures are generated. This is different from a theory that integrates concepts that refer to processing of information by individuals and concepts that refer to processing of information in activity systems. I believe that a program with that latter goal is feasible. It would involve maintaining the interpretations of concepts in the second column of Table 3.1 as properties of individual cognition, and coordinating those concepts with the kinds of concepts that are in the third column of Table 3.1. That is not the theoretical program I am pursuing. Instead, I am appropriating concepts and representations that have been developed in individual cognitive science and psychology and reinterpreting them as aspects of interaction in activity systems and social practice. This is aimed toward a theory that integrates the task and social aspects of interaction – or the semantic and systemic aspects of interaction – in the sense that it aspires to a theory that is primarily about interaction in activity systems, and includes analyses of structures of information that the participants have in common ground and generate in their activities of accomplishing tasks.

Level 1 Among the contributions of cognitive science, two of the most fundamental are models of text comprehension (e.g., Kintsch, 1998) and models of problem solving (e.g., Brown & Burton, 1980; Greeno, 1978; Newell & Simon, 1972). The information-processing theory explains routine understanding and reasoning as processes of constructing coherent representations that connect various pieces of information according to stored schemata and fill in pieces of information that are missing using stored inference rules The content of understanding depends on schemata that are retrieved from memory. Most understanding that occurs, in this theory, involves assimilation of information to known schemata, guided by comprehension strategies. The information-processing theory of problem solving similarly relies on hypotheses about representations of problem situations in the form of problem spaces that include the problem solver's knowledge of operations, procedures, schemata, and strategies. Problem solving consists of representing goals and subgoals and selecting operations and procedures whose effects will provide progress toward the main problem goal. Learning involves acquisition of new information structures, corresponding to actions that occur during problem solving, in a form that supports performance of the actions appropriately as components of procedures (e.g., Anderson, 1983; Newell, 1990).

The propositions and diagrams that represent information structures in the information-processing theory are usually interpreted as individuals' mental representations. This is not the only interpretation that they may be given. In the situative perspective, information is assumed to be constructed in processes of interaction in activity systems, and the kinds of representations of information that have been developed in cognitive science can be interpreted as referring to structures of information that are used and constructed in the interaction of people and other informational resources in activity systems.

In work that Randi Engle and I began in 1991, our strategy was to take the information-processing analysis of reasoning and understanding, developed in cognitive science, and embed it in a theory of conversational interaction, which we adapted from Herbert Clark's (1996) theory of conversational contributions. Our theoretical move was to hypothesize that constructive processes of understanding and reasoning occur in conversation through the joint actions of the participants. The information structures that are built are in the common ground that the participants construct in their interaction. In this view, the information-processing operations of cognitive theory are assumed to occur as joint actions in conversation, in which the units are what Clark and Schaefer (1989) called *contributions to discourse*. Each contribution includes, minimally, a presentation and an acceptance that signals mutual understanding sufficient for the participants' present purposes. A contribution may also include an action that signals uncertainty or confusion, or presents a question or a challenge to the initiating presentation in the form of an alternative idea or proposal. In that case, there has to be some negotiation to reach mutual understanding and completion of the contribution, to place new information in the common ground. Much understanding depends on the participants sharing of a vast amount of common ground (e.g., Hanks, 1996), a more inclusive version of the cognitive idea of schemata. Using these ideas, Engle and I developed analyses of some examples of conceptual understanding and reasoning in conversation that pairs of students had as they worked on a task of constructing a mathematical representation of a physical system (Greeno & Engle, 1995). The activity included reading instructions for a task in a workbook, setting up a physical apparatus that was designed to operate approximately according to linear functions, and constructing a table that represented the behavior of the apparatus with the parameter values specified in the instructions. Our analysis attempted to identify properties of information structures that students generated, corresponding to their understanding of the task, goals and subgoals that they adopted, and meanings of the symbols and other signifiers that they used in the representations they constructed. To explain these constructions of meaning, we hypothesized several kinds of schemata in the students' prior common ground, including general schemata involving participation in conversational interaction, more specific schemata involving accomplishment of school-like tasks, schemata about the operation of physical systems, and schemata about numbers and arithmetic operations.

Level 2 Level 2 involves understanding and reasoning that produces non-routine insights, which are novel for the participants. Accounting for novel insights has traditionally been challenging. In psychology, non-routine insights require flexible thinking, associated with gestalt analyses such as Duncker's (1935/1945). In more recent work in cognitive science, generative analogical reasoning has been studied and analyzed in detail (e.g., Gentner, Holyoak & Kokinov, 2001). In situations involving more than one person reasoning collaboratively, novel insights (for the participants) can be produced based on negotiation that occurs when they express differing understandings (Engle & Greeno, 1994). The value of diverse opinions in collaborative reasoning and understanding has been studied by Okada and Simon (1997), Schwartz (1995), Tudge and Rogoff (1989), and Rosebery, Warren and Conant (1992).

In detailed analyses of some episodes involving generative reasoning, we have focussed on a kind of interaction that we are calling *problematizing*. Engle and Conant (2002) identified this as an important issue, and Melissa Sommerfeld Gresalfi, Muffie Wiebe Waterman, and I examined some cases in which a group did or did not problematize an issue that they might have, which we have discussed in terms of semantic trajectories in conversation (Greeno, Sommerfeld, & Wiebe, 2000; Stenning, Greeno, Hall, Sommerfeld, & Wiebe, 2002). For an issue to be problematized, we hypothesize, alternative trajectories need to be considered. This can occur if the participants recognize an alternative and create a choice point or if one of the participants questions or challenges the group's current trajectory and succeeds in having the group consider whether a different trajectory might be preferable. This raises another issue in our analyses, the *positioning* of individuals in the participation structure of their classroom activity. In any episode of interaction, different individuals participate in different ways. Quite often, someone is initiating segments of activity, functioning as the director. Others are at least monitoring the actions of the director, providing approval or raising questions. Sometimes agency is distributed across two or more of the participants, with both or all actively contributing to the direction of discourse. This distribution of agency is important in the opportunities to problematize issues. If one of the participants is positioned so as to present virtually all of the information and ideas, with others positioned mainly as bystanders, it is difficult for anyone except the leading participant to introduce a question or challenge that is taken up by the group. However, if one participant initiates a contribution and another participant is positioned with significant agency for questioning or challenging that participant's presentation, rather than being positioned as a bystander, it is much easier for her or him to get the floor and introduce a question or alternative idea and have that taken up by the group.

Level 3 Issues at the next level involve students' engagement with learning tasks. Cognitive theories account for some aspects of these issues with models of students' understanding of problems and setting goals to solve them (e.g., Hayes & Simon, 1974). More generally, psychological theories of motivation include hypotheses about students' motivation to expend effort in tasks of specific subject-matter domains and tasks that have moderate perceived difficulty (e.g., Stipek, 1998).

In situative studies, students' engagement is considered as an aspect of their participation in classroom practices. Recent research on classroom practices has focused on structures of participation in which students are entitled, expected, and obligated to propose conjectures, raise questions and problems, and formulate explanations and arguments, rather than only being entitled to answer questions and solve problems given by the teacher (Ball, 1993; Ball & Bass, 2000; Brown & Campione, 1994; Hatano & Inagaki, 1991; Lampert, 1990). In an analysis based on our study of classrooms in the Fostering Communities of Learners project, Engle and Conant (2002) proposed that authority, accountability, problematizing, and access to resources are critical factors in supporting productive engagement by students in activities of disciplinary learning. Gresalfi, Martin, Hand, and Greeno (2009) studied ways in which students' competence is co-constructed by students and teachers in interaction.

Level 4 Issues at this level involve long-term conceptual growth and orientations toward learning practices. Psychological accounts of these factors include the large literature in cognitive development and general motivational orientations, such as achievement values (e.g., Graham & Taylor, 2002), orientation toward learning goals vs. performance goals (Dweck & Legett, 1988), and individuals' beliefs about themselves as learners and knowers (Belenky, Clinchy, Goldberger, & Tarule, 1986).

In a situative perspective, learning by an individual can be considered as change in her or his ways of participating in the practices of a community (Lave & Wenger, 1991). More specifically, conceptual growth in a domain can be considered as change in the discourse practices of a community, or in the ways an individual participates in discourse, that involve understanding of that conceptual domain. Situative studies have provided analyses of changes in discourse practices, in which participants' conceptual discourse can become more elaborated and integrated, can include representational practices used in conceptual reasoning and understanding, and can include more advanced forms of explanation and argumentation (Bowers, Cobb, & McClain, 1999; Greeno, Benke, Engle, Lachapelle, & Wiebe, 1998; Hall & Rubin, 1998; Lampert, 2001; Rosebery, Warren & Conant, 1992; Strom, Kemeny, Lehrer, & Forman, 2001).

A situative perspective can consider the ways that individuals characteristically participate in learning practices as aspects of their identities, as discussed by Gordon

(2000) and Packer and Goicoechea (2000). This perspective emphasizes “achievements [that] are less focused on what we want learners to know and know how to do, and more sharply focused on what it is that we want learners to become and be, i.e., compassionate and thinking interdependent members of humane human communities” (Gordon, 2000, p. 1), and focuses on the ways in which schools and considers “school as a site for the production of persons” (Packer & Goicoechea, 2000, p. 235).

In currently ongoing research, Melissa Gresalfi and I are beginning to develop ways of characterizing students’ identities in their participation in mathematics classrooms. Following Holland, Lachicotte, Skinner, and Cain (1998) and Wenger (1998), we focus on ways in which individual students are positioned in interaction. In our analyses, we distinguish two general aspects of students’ positioning. One, their systemic positioning, is in relation to other students and the teacher in the class. The other, their semantic positioning, is in relation the concepts and methods of mathematics. Systemic positioning – in relation to other people – involves the degree to which a student is entitled and expected to initiate contributions, to question or challenge proposals that are made by others, and to be given satisfactory explanations of meanings and methods involved in instructional tasks. Semantic positioning – in relation to the concepts and methods of mathematics – can involve what Pickering (1995) called conceptual agency, in which the individual makes choices and judgments involving meanings and appropriateness of methods and interpretations, or can be limited to disciplinary agency, in which the individual is only involved in performance of procedures that are established in the practices of the domain.[5]

Based on video records and interviews with students in two eighth-grade algebra classrooms, obtained over the period of a school year, Gresalfi (2004) has developed case studies of eight students, characterizing their mathematical identities in terms of persistent patterns of participation in classroom learning activities. She identified ways in which individuals differed regarding their tendencies to work independently or collaboratively, and in their efforts toward individual or mutual understanding of mathematical concepts and principles. The participation structures of the two classrooms differed significantly, with more emphasis and direction for students’ working collaboratively toward mutual understanding by one of the teachers. Identities of students were influenced by this difference in ways that are consistent with the idea that identities are constructed in interaction, shaped by both individual students’ proclivities and the affordances of the socially organized activity system in which they participate.

Two Examples from Our Previous Research

The holy grail for this quest takes the form of analyses of interaction that require systemic principles of participation in activity systems and semantic principles of meaning and information processing in combination to explain significant aspects of activity. This approach differs from some others in which it is assumed that social interaction provides a context for information processing, or that informational content provides a context for interpersonal interaction. Instead, I expect we will find it most productive to consider activity to be jointly systemic and semantic "all the way down," so that whatever the size of an event we choose to analyze, the appropriate analysis will include principles of both informational and interpersonal interaction that function at that grain size in order to explain the event.[6]

In this section, I present brief reviews of two analyses that we have conducted, in recent years, of episodes of interaction of different sizes. One of the examples involves activity in which students were intensely engaged over several weeks. The account that we have given of this involves principles that are mainly at level (3) in Table 3.1, involving ways that students were positioned in the learning activity. There are significant implications of our analysis for principles at level (4), involving students' positional identities regarding commitments and accountability to each other and to the conceptual domain of their activity. The other example is mainly focused at level (2) in Table 3.1, involving two episodes of classroom work with durations of a few minutes. The episodes contrast in a way that we attribute to the occurrence or nonoccurrence of a discourse feature of problematizing a substantive issue. There are significant implications of this analysis for principles at level (3) involving ways that students are positioned regarding each other and the conceptual domain of the activity.

I hope to accomplish two goals by reviewing these two examples. One goal is to provide cases in which the joint use of semantic and systemic explanatory principles is needed to account for significant aspects of the students' activity and to show that the operation of these principles at different levels of analysis are interrelated. The other goal is to set a stage for the analysis I then present of material from the Wisconsin Fast Plants® tapes. In that analysis, I conclude that we need to distinguish between two aspects of conceptual agency in classroom discourse: for generating variation (problematizing) and for contributing to selecting which alternatives become part of the common ground (resolving).

The explanatory principles that we have offered to account for significant aspects of the two cases in our previous research involve similar systemic and semantic aspects of interaction, functioning at different levels. The systemic principles involve ways in which students are positioned in interaction, that is, how they are expected by others and themselves to participate in relation to the other participants. The semantic principles involve ways of achieving coherence of information, including alignment of the situation with the goal of a task. Systemically, we have hypothesized that positioning students with authority, accountability, and commitment contributes to their productive engagement in the disciplinary activity of the class. Semantically, we have adopted the assumption that successful reasoning corresponds to achieving a coherent network of information, which includes alignment of meanings and propositions that refer to states of affairs in the situation and to concepts and principles in conceptual domains that the participants have access to. We hypothesize that processes that contribute to successful reasoning include detecting inconsistencies in the current information structure, often involving assertion of propositions that are inconsistent with principles of a relevant conceptual domain. Reasoning processes need to include problematizing inconsistencies by taking them up as discourse topics and resolving the alternative interpretations or opinions that are at issue.

These two kinds of principles are inherently interactive. Positioning with authority and accountability for inquiry supports participants in presenting alternative opinions and interpretations and dealing with them seriously, striving to resolve the alternatives in ways that are consistent with the facts at hand and with accepted conceptual principles. And students who are entitled and expected to generate and consider alternative interpretations and proposals for goals and actions in working on tasks need to draw on information, concepts, principles, and practices of explanation and argumentation to formulate and support opinions, which they can express if they are positioned with authority, accountability, and commitment in relation to other people. Being positioned to have opinions and to explain and defend them requires resources of information and practice of explanation and argumentation in the conceptual domain. The actions of forming opinions, explanations, and arguments in a domain require positioning with conceptual agency (in Pickering's (1995) sense), involving active choices, judgments, and evaluations that are not determined by standard practices. And the discursive activities of problematizing issues and resolving different opinions require systemic positioning in interpersonal interaction in which individuals are entitled, expected, and committed to presenting opinions and arguments that differ from those of others, to considering alternative positions and arguments, and being open to the possibility of changing their positions based on evidence and argument in the discussion.

An Extended Controversy

The analysis involving the large episode that I discuss here involves activity that occurred over several weeks in two fifth-grade classroom in Brown and Campione's (1994) Fostering Communities of Learners program. My discussion here draws on the analysis given by Engle and Conant (2002)[7]. The topic was endangered species, and each of the groups studied and wrote a report about a species. There were two classrooms working in parallel on the endangered species unit, and each of them had a group studying whales. A controversy developed about whether killer whales, or orcas, were properly classified as whales or as dolphins. The issue was significant because if orcas are not whales, then information about them would not properly belong in the group's study. The question arose because on a field trip to Marine World, a staff member said that "killer whales aren't whales, they're dolphins," At the time, the group's research included a significant effort of study about orcas, and removing the information about orcas would mean that that work would not contribute to the group's product. But the controversy engaged the students with more intensity than we would expect if it only involved doing some additional work. The two sides had leading advocates, evidence was presented and called into question from both sides, and the shift in opinion from a majority believing that orcas are not whales to almost all the group members believing that they are was an important feature of the group's history of research.

Engle and Conant's (2002) analysis identified features of the classroom practice that they hypothesized were significant in supporting the initiation and maintenance of the extended, intense controversy. Their analysis showed ways in which the teacher and students constructed positioning of the students with authority to form and question opinions on the issue and to construct and evaluate arguments on each side. They also were accountable for presenting their opinions and arguments to each other, for considering the opinions and arguments of other students, and for arriving at a conclusion that all members of the group accepted. The classroom practice generally encouraged problematizing issues in the subject matter, and the students had authority and were accountable for resolving the issues that arose, including the classification of orcas, using evidence and sound argumentation. Their account makes the orca controversy a prime example of an extended learning event whose explanation includes systemic and semantic principles of interaction, functioning integrally. Students were positioned generally to use information from texts and other sources to form opinions about the species they were studying, and when the disagreement about classifying orcas erupted, one of the teachers organized the students studying whales into a discussion, saying that both sides had "good points." The teacher explicitly directed the group to resolve the issue, affirming that they had authority to arrive at a conclusion and were accountable for doing that. They were enjoined to attend to each others' "good points" and to support their positions with evidence, which required them to process information from texts and formulate coherent explanations and arguments (This discussion lasted 27 min and was what the students called their "big ol' argument."). In the students' final report, they wrote that they had disagreed about the proper classification of orcas, and that the issue also had not been resolved by scientists.[8]

Correcting a Course, or Not

My second example involves two brief episodes in a middle school mathematics classroom using a unit of the Middle-school Mathematics through Applications Program curriculum. The unit, called Guppies, uses a software program called Habitech, which supports construction of models of population growth and decline. Students choose parameters for functions that change population size on an annual or other temporal basis, including birth rates and death rates, and the program runs simulations based on the functions that have been defined. Video material obtained by Rogers Hall and his associates were analyzed in a group that included Hall, Keith Stenning, Melissa Sommerfeld Gresalfi, Muffie Wiebe Waterman, and me. This analysis, along with others, is reported in Stenning et al. (2002).

In this example, we used concepts of positioning and information processing in explaining significant aspects of the activity we observed, as we do for the orca controversy. However, our analysis and explanation were at a more detailed level in this example. Here we hypothesized ways in which aspects of moment-to-moment interaction can be explained in terms of students' positioning and their processing of information.

In both of the episodes of this analysis, the group member who was most directive proposed and was beginning to carry out a procedure for solving the problem at hand, and the procedure was incorrect. The episodes provide an interesting contrast because in one of them the group discovered the error in the procedure and adopted one that was more valid, and in the other episode they did not, in spite of the procedure's being questioned by one of the students. We explain the difference in terms of a threshold for problematizing an issue, which is partially determined by the positioning of students in their participation structure. We hypothesize that the threshold was exceeded in one case and not the other because of a difference in the strength of information that was presented by the student who questioned the procedure that was being applied.

The first episode occurred during a pre-unit assessment, when the students worked on a problem involving a population before they were introduced to the computer-modeling environment. A situation was described involving a grain elevator in which 20 mice had been discovered. The students were to make reasonable assumptions about frequency of mouse reproduction and size of litters and predict how many mice there would be after 2 years. They assumed that mice reproduce in couples, and they discussed likely frequencies and sizes of litters, settling on reproduction once every 3-month season (hence, eight cycles in 2 years), and an average of four pups per litter. They inferred that from the initial 20 mice, there would be 40 pups added to the population. In the following excerpt, M and K worked out the number of mice after 2 years based on a linear process, that is, 40 pups each season times 8 seasons, added to the initial 20 mice. L, however, noticed that this calculation did not take into account that the population of mice increased with each cycle, and that the number of pups should take the new members of the population into account. L challenged the procedure by stating an alternative assumption that each cycle would produce four pups per couple of that cycle's current population. (Her explanation included an effective gesture, expressing the pairing of mice that had been born previously and their production of pups.) M and K accepted this alternative, and they proceeded to calculate the number of mice based on the assumption that the mouse population increased exponentially.

60: M. so there's ... equals 40 babies each season
65: M. it's three hundred and twenty
66: K. (inaudible) is that including adults?
67: M. no, three hundred and twenty plus twenty
69: M. by the end of the winter
70: M. three hundred and forty mouse ...mice ... mices. OK.
73: Now we need to make a graph of it ...
182: M. so let's see ... the first season is over here (making a mark on the graph)
183: L. xxxxxx wait a minute
186: M. and then sixty plus is going to be a hundred
189: L. wait a minute its forty (gestures a triangular shape) OK it's forty right?

```
190: L. and then you have to pair those up (brings hands
        together) and then they have kids (spread hands apart,
        while K and M looked at her confused)
192: M. oh yeaaah (embarrassed, laughing at himself) we were
        doing it ...
194: L. That's a lot of mice
195: K. gosh that's a lot of nasty mice
```

The second episode in this example involved the same group of students, working later in the unit. They had a worksheet called "Building the birth rate," which directed them to calculate a birth rate that they would then enter in a function on the computer interface. The worksheet asked them to make an assumption about the age and sex distribution of an initial population of ten guppies, then based on data from a reference source to calculate the number of fry that would be born in a reproduction cycle in that population. That number was to be reduced by 95%, the proportion that are eaten by the mother guppies immediately after they are born. This would leave a number of guppy fry that survive. This number should be divided by the initial number of guppies (in this case, 10) to provide a birth rate that the students were directed to enter into the computer model.

The students had arrived at a number of fry produced by their assumed distribution of the initial ten guppies, when M proposed that they could use a shortcut. Rather than dividing that number by the initial population size (10) to arrive at the percentage birth rate, M proposed that the percentage given as the survival rate (5% of those born, which they misremembered as 4%) would be a suitable number to enter into the program. L expressed confusion about this calculation, and M responded in a way that was conversationally appropriate, giving L an explanation of its sufficiency. L did not accept the explanation, but M proceeded to enter the value that he referred to as the survival rate into the program.

```
444: M. hey wait wait wait ... no but listen. If 4% of the
        frys survive why don't we just forget about the fry
        survival and just put that amount for the, for how much
        are born
445: L. because the number born are not how much survived
446: M. yes. yes, the ones who survive are the ones we count,
        not the ones who are dead because we don't make room for
        the ones that are dead
453: M. OK you know how 4% the whoooole fry who were born
        survive so why don't we just put 4% on the guppies birth
        because that's how many are going to survive
454: L. I get what you're saying because why put however many
        more guppies in when they're just going to die anyway?
455: K. so why not just put 4% because that's how many are
        surviving/ that's how many we're going to count
497: L. but what's that 4% ?
```

```
498: K. the ones that survive
499: M. The ones that actually survive fryhood
501: L. Yeah, I know, but how many of the guppies are 4% ?
502: M. we don't know, we'll let that mechanical thing work
        and tell us (M moved to the computer to enter the
        parameter in the program)
```

To sketch our interpretation of this pair of episodes, we need an explanation of why the group's threshold of problematizing an issue was exceeded in the first episode and not in the second. We believe that both systemic and semantic principles are needed for the explanation. A salient difference between the two episodes is in the significance of the information that L presented. In the first episode, L's challenge included an explicit model of the situation that was more consistent with the students' model of mouse reproduction than the implicit assumption of a linear process. In the second episode, L questioned M's procedure and expressed confusion, but did not offer an account of the semantics of the parameters in the way that she had in the first episode. Providing an explanation makes a stronger case for changing what a group is doing than only expressing uncertainty. We hypothesize, then, that the problematization of Episode 1 and not in Episode 2 can be explained by L's presenting information in Episode 1 with greater force than the information she presented in Episode 2. The interpersonal positioning of the students in both episodes supported M as the main initiator of information and action and supported L and K as having opportunities to question or challenge what M said and did. The evidence they required for grounding contributions was significant, but not as strong as it could be. Weaker evidence of grounding can be used in groups where one of the members simply does the work and others follow without raising questions or disagreements. Stronger evidence for grounding can be used in groups that require strong evidence of mutual understanding, such as restatements, and that take up issues on which someone expresses uncertainty to reach mutual understanding explicitly. If this group's interpersonal positioning had involved significantly weaker evidence for grounding, it might not have taken up the issue of the form of the growth function in Episode 1. If the group had had significantly stronger evidence of grounding, it might have taken up the issue of the base line for calculating birth rates in Episode 2.

Putting this more generally, we hypothesize that the difference between Episode 1 and Episode 2 can be explained by combining principles of systemic and semantic aspects of interaction, working jointly at the same level of analysis.

Planting Abstraction in Representational Practice

In this section I present analyses of two episodes from the tapes that were provided by Schauble and Lehrer for our examination and discussion at the workshop. I hope to show that the analytical scheme that I have presented here provides an appropriate and useful lens for understanding aspects of the interactions in the episodes that I selected. At the same time, accounting for these examples requires a conceptual distinction that was not salient in the examples we have analyzed previously. Therefore, the results of this analysis extend the concepts and empirical materials that I have discussed in this paper.

The conceptual extension distinguishes between two aspects of discourse at level (3) in the scheme shown in Table 3.1. The aspects are problematizing and resolving. Discourse practices include patterns of information that are recognized as problems, and they also include ways of dealing with problems that have been recognized and taken up. We had previously considered practices that encourage problematizing in cases that I have reviewed here. In those examples, issues that were problematized were also resolved productively, with actively engaged participation of students. In the examples I discuss from Schauble and Lehrer's material, there were discrepancies in the ways that students participated in problematiziing and resolving, which requires a more complicated understanding of these concepts.

A concept of resolving is related to the concept of reconciling, which has been developed by Deborah Ball and Hyman Bass (Ball & Bass, 2000) in their analyses of videotapes of Ball's mathematics teaching (Ball, 1999). They pointed out that there are characteristically mathematical ways of proceeding when there are apparent differences between definitions or methods. Mathematical practice requires such differences to be considered as problems, and efforts are made either to show that the apparent difference is not real (the alternatives are equivalent) or to show that there is a difference and to make an appropriate modification in definitions of terms or specifications of procedures. I use the term "resolving" rather than "reconciling" because reconciling by mathematicians depends on technical mathematical analyses that are lacking in the kinds of discourse that we find in ordinary classroom discussion.[9]

More generally, Toulmin (1972) characterized processes of conceptual change as including a process of generating variability and a process of selection, which determines which alternative ideas, methods, findings, and interpretations come to be accepted and established in an inquiring community. He noted that in scientific disciplines and other communities that construct conceptual systems, the selection process involves forums of debate in which members of the community contest candidate concepts, methods, findings, and explanations. In a classroom, practices that generate alternative definitions, solutions, or methods support problematizing, and practices that consider alternatives and select one or some of the alternatives as acceptable or correct are that community's practices of resolving.

The Activity: Designing and Evaluating Representations of Some Data

As I understand the video records that we are studying, the learning activity was designed to advance students' ability and understanding in a representational practice. The instructional strategy was for them to design representations (the teacher called it "inventing displays") for a set of 63 observations that the students had obtained in their project of growing Wisconsin Fast Plants®. The teacher's instruction was to "organize the data" in a way that used a piece of graph paper, with forewarning that the representation would be used to answer two questions: What is the typical Fast Plant height and how spread out are they? The data were presented as an unordered list of numerals. Previous learning apparently included some experience with bar graphs and line graphs, which the students recognized as relevant for their task.

School learning activities generally have an intended conceptual domain located in the curriculum. I would classify the domain of this activity as descriptive statistics. Statistical practice includes representing collections of numerical data and identifying properties of the collections, including central tendency and variation. Statisticians' discussions of these processes do not depend on what the numerical data signify in a domain other than mathematics. References to mathematical entities (numbers, relations between numbers involving ordering and arithmetic and, later, more advanced operations) are sufficient to provide the semantics of statistical concepts. The discussion of graphical representations in the video records that we are studying is consistent with this practice. The central tendency was called the height of a typical plant, but the discussion of the concept was almost entirely about the location of a number in the frequency distribution. The discussion of variation did not refer at all to variation in heights of plants, just the dispersion of numerical data.

Having the assignment be a design activity potentially positioned the students with more conceptual agency than they would have in some other activities that can be used for learning to make graphs. They made choices about the physical arrangement of tokens on the graph and labels of the axes (if they had axes), especially whether the axis was labeled with a numerical scale (rather than just an ordered set of numerals). They were not authors for issues of what the representations would be used for. The questions that would be addressed using the representations were provided as part of the assignment.

Further, although there was not a prescribed form for the representation, it turned out that there was a form that was preferred – a bar graph of the frequency distribution of the 63 data points, with an axis labeled with all the possible heights in the range that had data (i.e., not just the values that had data points), and with data columns corresponding to intervals (called "bins").

Having the assignment be a design activity also ensured that graphs with different features would be constructed, providing opportunities to problematize issues regarding those features. However, in the episodes that I examine here, discussions of alternatives were less productive than in the two positive cases I mentioned earlier. I conjecture that the main difference was in the authority and accountability of students in these episodes, compared to the classrooms that we analyzed previously. In those cases, students were positioned to have to reconcile their differences among themselves. In the episodes I discuss here, an adult (Rich Lehrer in one case, the teacher in the other) provided the authority needed to decide between the alternatives that were presented.

Some Semantic Features of the Graphs

Stenning (2002) has argued that it is useful (actually, essential) to examine logical features of a representational system to understand cognitive issues of its use. By "logical," Stenning explicitly included semantic issues, particularly a distinction between features of the representation that are interpreted directly and others that are interpreted indirectly. For example, if the relevant property of a symbol for some aspect of its interpretation is its presence in the representation or is its location in the representation, then the interpretation is direct. But if a symbol's referent is determined by a convention that only depends on what the symbol is, not on any physical property of the symbol (e.g., the referential meaning of a word), it is indirectly interpreted.

In all of the graphs that students constructed, the heights of individual plants were represented by tokens in the graph. That is, the presence of a token (a numeral or an "x") meant that there was an observation in the data set corresponding to the token. Except for one of the graphs that skipped doubles, there was a one-to-one correspondence between tokens and data points. Although one group began to construct a graph that distinguished the identities of the different plants, in the graphs that the class discussed the tokens represented data points anonymously. That is, the identity of the observation could not be recovered from the token, except in those cases where only one observation had the value represented by the token.

One of the groups constructed an ordered list of the numerical symbols. In this case, the position of a token in the list corresponded to its magnitude relative to the other tokens. For example, the token with an equal number of other tokens to its left and to its right corresponded to the median of the distribution.

In the preferred representation, a set of possible values (limited to the range of observed values) was placed along an axis, either as a string of individual values or as intervals, with positions for all the possible values in the range. This arrangement of numerals was referred to as a scale. Tokens (numeral values or x's) were placed above the axis, forming columns of tokens. Then the horizontal distance of a column from the origin was a feature that could be interpreted directly as the height of plants represented by tokens in the column, and the height of the column was a feature that could be interpreted directly as the frequency of data with that value or set of values. When the symbols along the axis included all of the possible values (in the range of the sample), the horizontal location of any given token was determined by its value. The several tokens in a column collectively represented the set of observations with that value (or set of values), and the specific location of a token vertically in the column did not signify.

A Lesson in Abstraction

An aspect of learning a representational practice is to adopt conventions for what information can be obtained by interpreting a representation and what information cannot be recovered. The design of a representational form and the processes of its construction and interpretation include determining which aspects of the represented events or objects will be included and which will be omitted and, effectively, erased.

In Excerpt 5 in Appendix B, learning an abstraction was a key issue. The episode is an interaction of Lehrer with four students: Anneke, April, Jewel, and Wally. The students' task was to devise a representation that would "organize the data" of plant heights measured on Day 19. The data were presented as an unordered list of numerals (see Excerpt 1). At the beginning of Excerpt 5, RL arrived to see a coordinate graph with intervals of plant heights on one axis (bins of 8) and the other axis set up with values of something from 1 to 63. He got an explanation from April and Anneke, with a follow-up from Wally, that one of the boxes had the "numbers between thirty and thirty-eight." Then he asked for a further explanation of their graph.

RL found out that the labels on the y-axis were intended to refer to numbers that would identify the plants by the vertical placements of their symbols. We don't know how the group had arrived at this. In an earlier excerpt, in which this group worked mainly on designing the spatial array (e.g., there was considerable discussion of which side of the paper should have the values of the plant heights) they had noted that there were 63 data points, and they allowed for 63 positions along one of the dimensions [Excerpt 3, 0:11:34 – 0:11:46].

When Jewel had explained that plant numbers would correspond to positions on the y-axis, Anneke expressed doubt that this information was significant ("but if it doesn't matter"), and after RL confirmed that he understood about the plant numbers, Anneke raised the question explicitly and elaborated, "it doesn't matter what the names of the plants are" [Excerpt 5, 0:40:20], Jewel and April responded in defense of including the plant numbers, and Anneke gave a more elaborate argument for their not being needed [0:40:35 and 0:40:36].[10] In the fragment below, RL forcefully posed a rhetorical question, "How does [the information about plant numbers] help you answer your question?" [0:41:05]. Anneke replied, "It doesn't," RL agreed [0:41:13], marking this as the correct answer.

Excerpt 5 [0:41:05–0:41:13]

```
0:41:05 RL:       How does it help you: answer your question,
0:41:08 Jewel:    Well but ⌈you said-
0:41:09 RL:                ⌊if I call one Plant One and the
                  other Plant Two?
0:41:13 April:    It doesn't.
0:41:13 RL:       It doesn't.
```

April and Jewel held out a bit more, and RL left, cryptically remarking "Well you gotta kinda try to figure out what you're tryin to figure out. Okay, so fix it" [0:41:44]. When RL was gone, April said, "I agree with that, what Anneke's saying," apparently leaving Jewel as the sole supporter of including plant numbers in the representation. Jewel resigned, saying "Who wants to erase this? I don't want to."

[0:41:50]. Anneke and April tried to persuade her that the labels didn't need to be erased, but Jewel was un-reconciled. She and April exchanged "Naah"s, and Jewel erased at least part of the labeled axis [0:42:11].

What are the lessons in this, for the students and for us as theorists about learning in interaction? For the students, I believe there was a significant opportunity to learn about a semantic issue, selectivity that is inherent in representation. Representations have features that can be used to specify some aspects of the objects or events that they refer to, and there are other aspects of referents that cannot be recovered by interpreting features of the representational signs. Choices to include or exclude features for recovering information about referents can be utilitarian (does it help you answer your question?) or they can be built into standard practice of a community (that's the way a line graph really is) or refer to important features of the source of information (you have to organize the data). The students and RL problematized the issue of whether to include a feature that would support identifying individual data points in their representation.

The argument that won in this case was utilitarian (does it matter? does it help you answer your question?) That argument was presented by Anneke and reinforced (or enforced) authoritatively by RL. It is unclear how much of the substantive consideration was mutually understood. The case contrasts with the first episode of the Guppies example, where a student presented an apparently compelling argument for an alternative action, based on a model of the reproduction process that they were representing. In that case, there appeared to be an advance in understanding that led to mutual agreement to assume an exponential process, rather than linear. Here, and in the second episode of the Guppies example, the resolution appears to have been more of a concession and less of resolving alternative opinions. There is more than one way to settle an issue, and the process of reconciling, in which reasons for alternatives are presented and taken seriously, may be an important factor in conceptual learning.[11]

On the systemic side, there were lessons for the students about the permanence of choices made in a collaborative group. Previously, the group had settled on a representation including plant numbers, but at the end of this episode, the representation had changed. There were marks on paper to be erased, but the erasure removed more than the marks. It also erased a property of the representation in which Jewel appeared to be significantly invested.[12] (I imagine that the group's inclusion of plant numbers might have resulted from a discussion in which Anneke expressed some of the doubt that she expressed in the episode we have. In that case, the degree of settlement might have been tenuous, and Anneke may have taken the opportunity of RL's presence to advance her view at the expense of Jewel.)

As for a lesson for us analysts: I believe this provides another example of an event for which is it useful to combine semantic principles of information processing and systemic principles of interpersonal interaction to explain what happened. An account of the group's use of ordered numerical intervals requires hypotheses about their knowledge of the number system, the containment of numbers in intervals, and conventions of graphical representation where locations refer to numerical values. So does an account of their plan to use a second dimension of plant numbers, as well as their eventual decision to omit that variable.

On the other hand, systemic hypotheses about the students' positionings in the participation structure and commitments to positions in the discussion also seem to be required. The shift from including to excluding plant numbers occurred to Jewel's evident displeasure, which makes likely that she was committed significantly to having them. The argument against having them was sound, but it was not presented in much depth, and it is likely that Jewel did not adopt it on its merits. Therefore, the authoritative position that Lehrer held in the participation structure seems needed to account for the group's conclusion to omit the plant numbers from its representation.

Issues of positioning in classroom practice have implications for the opportunities students are afforded for development of learning identities, in the sense that Gresalfi and I are trying to develop that idea (Greeno, 2001; Gresalfi, 2004). One example is the interaction of Anneke, Jewel, and RL around the question of plant numbers. Anneke seems to have been quietly persistent in expressing her view that identifying individual observations "doesn't matter," and then RL joined her and authoritatively settled the issue, with the consequence that Jewel's and, apparently, April's view favoring inclusion of the plant numbers no longer prevailed. It is tempting to speculate that this episode may have exemplified significant aspects of Anneke's and Jewel's positional identities in the class, perhaps involving a pattern in which Anneke's presentations were generally taken up and often prevailed, and Jewel's more often being set aside. But for such a conjecture to be evaluated we would need to examine Anneke's and Jewel's interactions in a collection of episodes, and evaluate whether the suggestive pattern that occurred in this case was generally characteristic of their participation.

Learning to Scale

The other episode I have examined is in Excerpt 9. The class activity was presentation and discussion of graphs that had been constructed by the several working groups of students. The discussion, led by the teacher, considered four graphs in this episode. One was a histogram values in "bins" of ten, Two were ordered lists of numerals corresponding to the data points, and one represented each data point as a vertical line whose length corresponded to the value, with the vertical axis labeled with numerals corresponding to all possible values within the range. In the discussion, the teacher focused on properties of the graphs that "help you see what's typical and how spread out they are," especially the latter. At about the eleventh minute, the teacher introduced a hypothetical data point, asking what would change in the graphs if the point 255 (the largest value in the set) was replaced by 555 [Excerpt 9, 0:10:33]. The graphs that included locations for all the possible values (in the range) would have to be extended, whereas in the graphs that just listed values, the largest numeral would simply be replaced, without having to change its location. The teacher referred to inclusion of all possible values as having a scale, and concluded that a scale is useful "to help see how spread something is" [0:13:51].

Semantic Issues

I consider three semantic issues involving the informational contents of this discussion. One is abstraction, again. The second is the nature of iconic vs. symbolic representation or, as Stenning (2002) put it, whether a representation is directly or indirectly interpreted. The third issue is the introduction of the term "scale," and its meaning in relation to the concept of spread.

Abstraction

The identities of plants and their observers were erased previously, and the semiotics of the graphs was focused on aggregate properties of the collection of observations. In this discussion, the origin of the numbers as properties of a collection of plants was, if not erased, set far in the background. The concept of typicality was, arguably, focused on the typicality of a number or interval of numbers in the collection of numbers that the students were representing. Although it had the label "typical Fast Plant height," or an equivalent, there were no explicit references to the set of plants, in which a height of, e.g., 160 mm, was typical. In the case of spread, there was no reference to the plants (i.e., they did not refer to the "Fast Plant spread" or "spread of the Fast Plant heights"), and the discussion seemed entirely focused on the variability of numbers.

It is remarkable how seamless this abstraction was. The phrase, "How spread out they are," applied to a collection of plants, might be expected to refer to the spatial distances between plants in the ground they grow in. It was obvious to everyone in the classroom that the property of being spread out was not intended as a description of the locations of plants. No one expressed any uncertainty about whether they were talking about the amount of space that the collection of plants occupied.[13]

On the other hand, the intended meaning of the term "spread" apparently was not just how much space the symbols occupied in the graph, either. It turned out that the most approved graphical form had that property, but it was not discussed by the teacher that way. He did not ask, "Which graph has the symbols spread out more (or less)," but instead, "Which graph would be better to help you *see* that spread?" [Excerpt 9, 0:11:26]. If I am right that this did not refer to the collection of plants, what was "that spread" a property of? I believe it was mainly the collection of numbers represented by the numerals that were presented at the beginning of Day 27 (Excerpt 1). This isn't far from a meaning in which "that spread" would refer to a property of the collection of the measured heights of the class's plants. But very little in the discussion (that I found) maintained the connection of the numbers with the observations.[14] There was a set of numbers, and the amount of "spread" referred to differences between the numbers. "Why [that graph would] help you see the spread better" [0:11:26] referred, I believe, to the ease of interpreting a property of the graphical display as a reference to the amount of difference between the numbers that were represented in the graph. The preferred form supported a direct interpretation, with the spatial spread of tokens in the graph interpreted as referring to the spread of numerical values. Of course, this is just the way that statisticians think. But probably not gardeners.

The Concept and Representation of "Spread"

The teacher focused significant attention on the question, "Why [that graph would] help you see the spread better" [Excerpt 9, 0:11:26]. It turned out that he was inviting attention to the extent to which data were distributed across a wide range of values, and how that distribution could be perceived as a feature of the graphical representation. In the standard interpretation of a bar graph, heights of columns refer to frequencies of values of the variable, and distances between columns refer to differences between values, therefore, the spread of a distribution can be perceived directly. Stenning (2002) argued that the availability of direct interpretation is the distinctive feature of diagrammatic representations in contrast to propositional representations, which require indirect interpretations. Diagrammatic representations are constrained in ways that propositional representations are not. For many diagrammatic representations there are spatial constraints, which limit the locations at which symbols or icons can be placed, depending on their referential meanings. The teacher used this feature when he posed the question of whether a representation would be visually changed if 255 was replaced by 555. If the abscissa includes all of the possible values in the range (which the teacher called a scale) the location of a symbol is constrained by its referent in a way that it is not in the more propositional representations (e.g., a list of numerals), or in the representations that do not have the correspondence of distances along the axis with values of the variable. It is interesting that the authors of the list, for whom the typical entry and, especially, the spread, could not be interpreted directly with perceived features, included statements (i.e., propositional representations) to represent their judgments about the features ("We wrote the answer and how we did it and they didn't." [0:07:06]).

The favored graphs, which supported direct interpretations to answer the questions the teacher posed, are consistent with pedagogical practices that emphasize modeling, in the sense of constructing representations that allow mental operations that simulate significant conceptual processes. So moving a symbol farther away from the other symbols and gesturing to indicate a region of central tendency or an increase in the spread of a distribution are available in discussions of statistics and are easy to relate to diagrammatic representations, more than with propositional representations or formulas.

The Concept and Term "Scale"

The graph consisting of a list of numerals had just been discussed when the teacher posed the hypothetical situation where 555 was in the set. He indicated that with this value there would be "a much bigger spread." Then he declared that the change in the number list would involve replacing "2" in "255" with "5," and asked,

Excerpt 9 [0:11:03–0:11:04]

```
teacher: Would this graph (0.3) help you see that that's more
         spread out?
```

Two of the graphs had numerals along the x-axis corresponding to values that corresponded to measurements, with 255 at the upper end. The teacher noted that on those graphs, the 255 entry could just be replaced by 555, without changing its location, and asked,

Excerpt 9 [0:11:18–0:11:26]

teacher: Would that >would the graph itself< if you (0.3) could see that or if we did it on this one we had five fifty five here. Is there is there a graph up there that would be better to help you see that spread? than some other ones, and why >would it be< (.) why why would that graph help you see the spread better?

Jewel offered that one of the graphs with only the occupied values along the axis was

Excerpt 9 [0:11:46–0:11:47]

Jewel: ... really good because (0.6) you can like tell if like (1.1) if it goes farther like

There was a bit of defense by the authors of the list, saying that they would have put their numerals in a single line if they had had room. The teacher responded to Jewel's choice, saying

Excerpt 9 [0:12:26–0:12:39]

teacher: Okay so Jewel, you think (.) this graph by looking at it if I wrote the number (.) five hundred fifty-five right here *(pointing to a place on the upper end of the axis))* would be the (.) easiest graph to look at to see that (.) this has a lot of spread. Is that what you think?

Jewel: Um hm, (I) guess.

Without further comment, the teacher called on another student, Kerri, who chose the graph with 10-mm bins and all the possible values in the range of actual values. This was what the teacher apparently had been waiting for. He (implicitly) endorsed Kerri's choice, revoicing her presentation with a significant appropriating move of attributing to her that she was talking about a scale.

Excerpt 9 [0:12:48–0:13:27]

Kerri: ⌈⌈*((pointing to Group 3's graph))*
Kerri: ⌊⌊Well I think that probably this graph because (.) it lea- they still leave: (0.9) some spaces there, (0.8) in case there would be even though there's not, so that you can (.) really see how spread out it is because it (0.5) goes (0.3) thirties, (0.5) up to the most and you can see if when there's like (0.7) >how much< ⌈space is there between it
teacher: ⌊OH::.
teacher: >I see what you're saying< you're saying that there's some there's a scale down ⌈here on the bottom (2.1) an:d if it was five-hundred fifty-five they would well two-fifty's here so we'd figure it would be five fifty-five would be out ⌈here?
teacher: ⌊((*pointing to x-axis of Group 3's graph*))
teacher: ⌊((*pointing to a projected point beyond the end of Group 3's graph*))
Kerri: °Yeah.°
teacher: And then ⌈then you would see that number out there, and then it the graph itself would actually look like spread?
Kerri: ⌊H(hh)•

Actually, Kerri didn't mention a scale or extrapolating the scale beyond the values on the sheet of paper. Even so, the teacher invited Ian to comment on "what helps people see that spread if what, what Kerri is saying is true" [0:13:35].

Ian apparently had listened to Kerri and responded by rephrasing what she had actually said: "Uhm not, not just the numbers that we actually measured that are in between, but all of the numbers that are in between" [0:13:41]. The teacher persisted, and in a turn that had the form of rephrasing Ian's presentation, he added Ian to the group who realized that a scale was important:

Excerpt 9 [0:13:51–0:13:52]

teacher: SO:: this (0.2) having a scale down here, which is >one two three whatever it is,< (1.4) would help you see spread (.) better?
Ian: Yeah.

The teacher elaborated on the point, with a transitional (rhetorical) question, "Does anyone not quite understand what Ian is saying?" [0:14:02]. He finished his elaboration, "so long as you have a scale on the bottom, I think that helps people determine how spread something is" [0:15:15].

The next student, Kristen, selected the graph that represented heights of individual plants as vertical lines with numerals at their tops, with indications of all possible values along the vertical axis.

Excerpt 9 [0:15:22–0:15:37]

Kristen: Well I'm not (0.6) sure but (0.5) I'm not I don't
(0.9) well (0.5) I think (0.7) this: (0.9) graph
might help you, down there because of the like the
line (0.2) up here (0.6) might get higher but I'm not
sure how this graph works really but (   )

The teacher moved this graph from its partially obscured position so it was visible and appropriated it for another example of scale.

After establishing that changing the value 255 to 555 would require a point higher up the y axis, the teacher asked questions apparently intended to elicit the concept of scale as the answer. First, he may have started to say, "So they have a scale," but asked, instead, "What is that, over here, ten twenty thirty . . ." [0:16:06]. Instead of answering, "a scale," a student replied "The y axes?" [0:16:20]. Trying again, the teacher asked, "and it's also an, April?" [0:16:14], who answered, "A bar graph" [0:16:19]. He continued with additional scaffolding:

Excerpt 9 [0:16:22–0:16:40]

teacher: And they've done something else to it they just
didn't write (0.8) >there's< something else that's
special about it (0.8) that would help (.) that
you'd also be able to see it
teacher: Ian?
Ian: You can tell how high it is
teacher: Well how can you tell how high it is?
Ian: (Start)
teacher: What ⌈did they do to it?
Ian: ⌊Cuz it's higher on the (.) graph
teacher: Because they,
Ian: Put a scale?

Finally! The teacher confirmed this contribution. "Yeah, they could put a scale on" [0:16:40]. And after indicating that 555 would be about twice as high as 250, he closed the interchange with, "So are we agreeing that scale is an important thing? To see help see how spread something is?" [0:17:00–0:17:03]. No one objected.

I have focused on three semantic aspects of this episode of classroom discussion; abstraction (it was almost entirely about a distribution of numbers; references to plant heights were far in the background); representation of spread as a directly interpretable property of some graphs more than others; and the feature of having a scale that includes all the possible values, which is a constraint that supports direct interpretation, especially of spread. These are all legitimate aspects of statistical practice, which the students experienced by working with data they had collected.

Systemic Issues

Systemically, students were positioned as designers, interpreters, and evaluators of representations. Collectively, they constructed representations that had significant variety. One form emerged, through the teacher's management of discussion, as being advantageous. Therefore, the activity provided students with an opportunity to learn something about how the form of a bar graph, with values of the variable partitioned in equal intervals and including all the possible values of the variable, provides a representation in which the features of typicality and spread are directly interpretable. The key concepts – typicality, spread, and scale – were in the discussion because the teacher put them there. But he did not introduce these "out of the blue." Instead, he arranged to have student products to ground the discussion of the concepts.

The representational practice that students participated in included significant conceptual agency at the level of designing and explaining graphical representations. This positioned the students differently and, we can hypothesize, resulted in a different relation of agency in the practice, than had the teacher told them how to construct bar graphs of these data and explained the advantageous features didactically.

On the other hand, the opportunity for conceptual agency was also limited. The concepts were illustrated in the discussion, and students participated in the discussion that included the concepts. However, meanings of the concepts seem to have been drawn out from the students, rather than having been initiated by them. Thus, their agency in understanding was primarily animating, rather than authoring (Goffman, 1981), or mastering, rather than appropriating (Herrenkohl & Wertsch, 1999) the discourse patterns (phrases, meanings) that the teacher made available to them.

The issue of alternative formats that defined the issue of scale was problematized in the discussion, but it did not engage students in the ways that we observed in our study of FCL classrooms, at least as far as we can tell from these records. It is unclear whether organizing an extended discussion about the merits of leaving spaces for unobserved values of a variable would have been productive for learning. But resolving the difference by the teacher eliciting a step toward the received view and then presenting it with attributions to the students who took or agreed with the step, created a different positioning toward the concept than could be imagined if the resolution had involved a more symmetrical (and, of course, more time-consuming) discussion.

Conclusions

I have tried to accomplish two things in this paper. First, I have reviewed the current state of research in the perspective that I call situative, emphasizing that this approach treats cognition as an aspect of interaction of individuals with each other and with the material and informational systems in their environments. Analyses of interaction are conducted at multiple levels that differ in the complexity and time scale of the phenomena that are analyzed. I reviewed two cases from our previous research that focused mainly at levels (3) and (2), respectively, of Table 3.1 in this scheme. These analyses emphasized positioning of students with authority, accountability, and competence, and practices that encourage problematizing issues that can lead to conceptual growth when they are taken up.

The new material in this paper came from analyzing two episodes in the Fast Plants videos that Schauble and Lehrer provided. These examples differ from our earlier examples in the way that issues were resolved. In all of the examples I discuss here, the students were positioned with authority and accountability for generating alternatives that were taken up in their group or in class discussion. But in the process of resolution, authority was distributed differently in the Wisconsin examples than it was in our earlier examples from FCL and MMAP. In the orca-controversy and the mouse-reproduction examples, students were positioned with authority and accountability for resolving the issue that was problematized by the alternatives they generated. In the plant-number and graph-scale examples, adults led the students to positions that resolved the issues.

Theoretically, the difference shows a need to differentiate the concepts of authority and accountability in the positioning of students to include what students are authorized and accountable for. In the Wisconsin examples, students had authority and accountability for constructing representations, which were expected to vary and, thus, provide alternatives with differences that could be problematized. But when issues were problematized, the discussions moved toward resolutions with positions that were authorized by adults. As a result, students did not generate arguments based on principles to support the alternatives that they might have had they been positioned with authority and accountability for resolving the issues themselves.

In relation to Toulmin's (1972) characterization of conceptual change, the practices of this classroom positioned students with initiating agency in the process of generating variability. They produced representations that varied significantly. Their role in the process of selection was less generative. The selection of a form, at least in each of these two instances, was guided quite strongly by an adult.

Putting this in another way, the difference also shows a need to differentiate the concept of cognitive demands of instructional tasks, as this has been developed by Stein and her associates (Stein, Grover, & Henningsen, 1996; Stein, Smith, Henningsen, & Silver, 2000). The concept of cognitive demands distinguishes between requirements of reciting from memory, performing a procedure without conceptual connection, performing a procedure with conceptual connection, and "doing mathematics." I would judge that the task of constructing graphical representations involved doing mathematics, but the contrast with our other examples shows that doing mathematics can occur with different participation structures, which may have consequences for what students learn in their activity. The positioning of students in an activity of doing mathematics may include more or less authority in resolving mathematical issues, and this may be significant for their learning outcomes.

This distinction invites counterfactual speculation about the kind of practice that the Fast Plants class might have had in which students would have been positioned to participate with more initiative in the process of resolving differences between alternative representations. It would involve establishing forums of debate about advantages and disadvantages of representational conventions. Like all such issues, this involves dilemmas of how to allocate time to different aspects of classroom activity. It would take significant time to establish a discourse practice of debating properties of different representational forms. To decide to do that would depend on a judgment that the value of students' participation in such debates would be sufficient to offset the loss of participation in other activities that would have to be allocated less time. Perhaps further research that analyzes ways in which such participation contributes to students' understanding and identities as learners would be valuable for us to pursue.

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Notes

1. The following paragraphs are adapted from an earlier presentation of this theoretical approach (Greeno, 2001).
2. I refer to my version of this effort as a "situative" approach. I was introduced to these issues and ideas by Jean Lave, Brigitte Jordan, Lucy Suchman, and others who characterized their perspective as "situated action," "situated cognition," and "situated learning." I make the small syntactic change to "situative perspective" or "situative analysis" to make less likely the unfortunate misconception that only some action, cognition, or learning is situated.
3. I previously (including in a draft of this paper) referred to these two approaches as "working from the inside out" and "working from the outside in." I am grateful to Eric Bredo for pointing out that this is a poor way to characterize the distinction. A very prevalent strategy takes the cognition-to-interaction approach, working from the inside out – it treats individual cognition as the fundamental process and works to account for the influences of other people and systems in the environment as contexts realized as different experimental treatments. The approach taken by Dunbar, Okada and Simon, Schwartz, and others was different; in these studies cognitive processes such as analogical reasoning, generating hypotheses, or representing abstractly were attributed to interacting groups of individuals. Recent interactional analysis of cognition do not "work from the outside in" in the sense of hypothesizing intra-individual processes that are distinguished from processes at the level of activity systems and social practices and that inherit properties of the group processes (although Vygotsky's (1987) writing encourages hypotheses along those lines). Instead, cognitive processes such as perception, remembering, understanding, and reasoning are considered as functions of activity at the level of activity systems and hypotheses to explain cognitive accomplishments are proposed in terms of hypotheses about processes of interaction.
4. I say "basically correct" because calling the aspects "task" and "social" doesn't match my understanding. In my view, tasks are social. What constitutes a task, and which tasks are

important for one to participate in, are aspects of social practice. I prefer a distinction that I have called "informational" vs. "interpersonal," although that is also problematic. Perhaps "semantic" and "systemic" would be useful as terms for this distinction, where semantic aspects involve the referential meanings of concepts and assertions that are made and relied on in activity, and systemic aspects involve the interactive processes of that activity.

5. In disciplinary agency, the result of a process is determined by accepted rules of a practice, if the agent performs the procedure correctly. In conceptual agency, the result of a process depends on choices that the agent makes, including the way a problem is formulated and what procedures to use. Pickering discussed ways in which scientific, mathematical, and engineering practices involve "dances of agency," combining conceptual agency and disciplinary agency, especially in mathematics, or conceptual agency and material agency, where outcomes depend on the way apparatus functions in the world, especially in physics.
6. The assumption that systemic and semantic principles function jointly at all levels is weaker than alternative assumptions that are needed to justify treating either of them as a context for the other. For one of these sets of aspects to function as context for the other, the two sets of aspects have to be factorable in a way that I believe is empirically unwarranted.
7. The initial phase of this analysis was conducted by a group that included Randi Engle, Faith Conant, Muffie Wiebe, Frederick Erickson, and me. Engle and Conant completed the analysis and wrote the report.
8. This isn't quite right, of course. Biologists are clear about how they classify marine mammals. But the students arrived at a reasonable interpretation, given their sources. Whales and dolphins (including orcas) are all members of the order of cetaceans, but are in different families. Thus, at one level, it is appropriate to distinguish orcas from whales. But cetaceans are often referred to collectively as whales; for example, books that are about whales (in this sense) usually include discussions of orcas.
9. I am grateful for a conversation with Hyman Bass in which he corrected my previously inaccurate understanding of the concept of reconciling.
10. It is possible that the group had a previous conversation along these lines. It could be informative to see tape, if there is some, of this group's decision to use plant numbers as the vertical dimension on their graph.
11 It might be useful sometimes, in situations like this, to invite discussion of circumstances that would make it valuable to maintain a representation that lets the identities of individual data points be recovered. For example, if other data were stored with each data point, being able to identify individual data points from the graph of plant heights could be useful for investigating relations between variables. Such a discussion could lead to the same conclusion as this group reached, but it could be based on a judgment that preserved the merits of the rejected alternative, just not for this situation.
12. O'Connor, Godfrey, and Moses (1998) analyzed an extended event in an Algebra Project classroom that focused on a student's "missing data point." An observation by one of the students had been lost, and the class worked on what to do about that over an extended period. O'Connor et al. documented that the class's concern was not limited to having a complete data set for its own sake, but also for not leaving out the student's personal contribution to their joint project.
13. Hall, Stevens, and Torralba (2002) described an instructive (and delightfully interesting) interaction between some biology researchers and a statistician. The biologists had taken samples of termites in a spatial grid, and had data about the chemical composition of wax from the termites collected at each site. They wanted advice about how to evaluate their data to investigate whether there was a previously unidentified species of termite in their woods. The statistician was thinking about distances between populations of data that could be analyzed by some kind of discriminant analysis. The conversation was delightfully confused for some time while the biologists thought he was talking about distances between the locations at which the termites had been captured.
14. When the teacher introduced the hypothetical 555 mm plant, he said, "I'm wondering which graph would show better in (1.3) the spread. So let's let's ignor:e two hundred and fifty five

for a minute and say instead of that plant being >two hundred and fifty five< (0.5) *((writing on board))* it was five hundred fifty five. Oka:y. Does that does that feel like it's quite a bit different(0.4) than two fifty five 'kay?" [Excerpt 9, 0:10:28–0:10:42] This is the only reference to plant heights that I found in the discussion of spread. I found no explicit references to variation in the heights as an aggregate property of the set of plants.

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Chapter 4
A Commentary on Incommensurate Programs

Douglas Macbeth

Introduction

In puzzling through what work this commentary might do, especially in light of the care with which James Greeno has framed and addressed his chosen task – to bring cognitive and interactional analytic traditions into a formal, theoretical alignment – I returned to some of the prospectus materials Tim Koschmann had submitted that brought this collection to press. Prospectus reviews are a kind of "institutional action" in which, in the end, what's worth reading gets decided for the rest of us. In the particulars here, though the reviewers were to a person impressed by the collection of contributors, and though the weight of reviews was clearly positive, it wasn't entirely so. The prospectus was taken to task for a few things, one of which seemed deeply obliged: How would the collection further our theoretical understanding of teaching and learning, and thus our resources for effectively designing them? A tough sell, I thought on Tim's behalf, yet an unavoidable one. Educational research began with the promise of instrumental "goods." This was part of its appointment as an applied science, and this instrumentalism has been with us ever since. On the other hand, this is precisely what James Greeno is promising to deliver.

So, one promise of the collection was that by reading into relevance major developments in the "social turn" of educational studies we might leverage new ground for our theoretical and design tasks. No one has taken up that responsibility more seriously or directly than James Greeno, not simply here, but across an extraordinarily productive career. Though theoretical in its presenting terms, one can clearly see that he is pressing for new and hopefully effective instructional design resources, as he has for more than 30 years. His paper, as we should expect, is finely woven and closely, effectively argued, and what I want to do in this commentary is sketch a way in which we might break into it and recover some alternative readings of

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various phrases and formulations – and thereby tasks and authorizations – that we seem to hold in common, and yet may understand very differently.

At least some of the resources he is pressing into service stand at some distance from the intellectual habits of educational study. Colonized from its very first days by materialist metaphors of mind, process–product designs, and the black boxes that accompany them, the social or social–practice or "linguistic turn" in educational research has easily been the most visible innovation of the last 25 years. It is both a conceptual innovation and, perhaps more significantly, a cultural one. By "cultural" I mean that analytic communities have their cultures, from archeology to test–item construction. Literatures, controversies and intellectual histories are attached, as well as best judgments about what good questions are, instructive analyses, new thinking and the rest. Part of my larger argument is that the social turn in educational studies has been taken up with a greater enthusiasm for its future – the possibilities of novel analytic returns – than for the histories and analytic cultures that deliver the "turn" for us to turn to. This part of my argument and commentary is quite interested, in that the work I do has everything to do with the analytic history of situated action.

Jim Greeno's home is among the first generation who leveraged social science from computing science. He has been an innovator in cognitive studies nearly as long as cognitive studies have been with us, and in his position paper he is proposing further innovations for the field – an integrated theory of semantics and systemics – that would achieve a suture between cognitive science and interactional analyses in the domain of learning. How to do it is the question, and his title announces his chosen way, through the insights of a "situated perspective."

This is of course the work that stands at some distance from the analytic cultures of educational research from Thorndike forward. It is sociological and ethnographic in the main, with strong attachments to philosophies of action, natural language and social science that are decidedly not "scientistic." Early on, he cites the works of Jean Lave, Brigitte Jordan and Lucy Suchman as benchmarks. We can be assured that Lave and her colleagues were beneficiaries of prior literatures. They might include Dewey's "epistemological behaviorism" (Garrison, 1994), Mead's philosophy of the present (1932/2002), Polanyi's studies of tacit knowledge (1967), Goffman's "Neglected Situation" (1964), Geertz's "thick description" (1973; via Ryle, 1949), and, perhaps especially, Garfinkel's (1967) ethnomethodology of situated action, and Sacks' (1992) sequential analysis of natural conversation (Sacks, Schegloff, & Jefferson, 1974).

On consideration of Jim's acknowledgments to Lave et al., the relevance of ethnomethodology and sequential analysis for understanding the situated perspective may have particular weight. Brigitte Jordan was a graduate student at the University of California at Irvine when the late Harvey Sacks was developing his extraordinary work and collaborations on natural conversation, work cut short by his unbelievable death in 1975. She knew Sacks and his analytic program, including his on–going collaborations with Harold Garfinkel. As intellectual history would have it, Jean Lave was a junior faculty member in Anthropology at Irvine at the same time and a colleague of Sacks. My understanding is that John Seeley Brown was also on faculty at Irvine at the time, and that he and Jean were aware of Sacks' initiatives and the work of Garfinkel and his students at Irvine and UCLA.

There's a puzzle with respect to Suchman's graduate curriculum, as there were no faculty in Berkeley at the time who were teaching either ethnomethodology or sequential analysis. And though John Gumperz knew Harold Garfinkel personally and professionally, and edited collections that included ethnomethodological studies, to my knowledge Suchman did not study with Gumperz. He joined her committee late in her graduate program, after the completion of the copier study as a project for Xerox PARC. Yet while the intellectual history may not be clear, what is quite clear is that *Plans and Situated Actions* (1987) is indebted to prior readings in ethnomethodology and sequential analysis on virtually every page. All of which is to say that when we inquire into the currency of the situated perspective in educational studies, we will be led to many places, but especially to prior work and formulations of situated action that are distinctively, even radically, sociological.

We can further observe, and it's quite unexceptional in intellectual history, that while Garfinkel's and Sacks' initiatives were caricatured as "West Coast Sociology" in the early 1970s, the early expressions of the "situated perspective" in educational studies quickly gained interest a decade later. They emerged from developments at Berkeley, XeroxPARC and Stanford that were more than coincidental with the arrivals of Jim Greeno, Alan Schoenfeld and Andy di Sessa at Berkeley in the early 1980s, the recruitment of kindred social scientists to Xerox, the founding of the Institute for Research on Learning (IRL), and the later arrival of Jean Lave.

Others know this history far better than I do, and it was by no means *only* a west coast development, as the intellectual histories of the contributors to this volume will show. In the late 1970s, for example, Fred Erickson and Brigitte Jordan were at Michigan State running a working group for the study of interaction in real time, the Interaction Analysis Lab.

There were other persons and places too, such as Aaron Cicourel and his education students at UC San Diego, Hugh Mehan and Robert MacKay principle among them, and also Ray McDermott's early work on both coasts. Ray's dissertation "Kids Make Sense" (1976) is perhaps the most widely cited dissertation study never published. His title is a virtual announcement of the "situated perspective." Perhaps the earliest institutional site of kindred thinking was the "Kiddie Lab" at Rockefeller University founded and administered by Michael Cole and George Miller in the early 1970s (Miller, 1977). Devoted to child language and cognitive developmental studies, it became a major cross roads for interdisciplinary study taken up with the primacy of action in social worlds, whose travelers included Lave, McDermott, Sacks, Schegloff and many more. I also want to make mention of Jenny Cook-Gumperz' 1977 journal article "Situated instruction: Language socialization of school age children," the series "Working Papers in Sociolinguistics" edited by Richard Bauman and Joel Sherzer and published by the Southwest Educational Development Laboratory in Austin, Texas, the editors of *Anthropology and Education Quarterly*, the work of Courtney Cazden, Marilyn Merritt and a host of others, all of whom were finding their resources outside of education, from sociology, anthropology and linguistics, and bringing them to educational tasks and settings through the 1970s and 1980s. And of course the soup is thicker still; the insights of situated order, action and meaning have been developed in a great many places throughout the last century.

What I'm angling for here is two observations. The first is the great distance and traverse that brings the "situated perspective" to educational studies. The second is how many of the contemporary interpreters of the social turn in educational research have disciplinary homes and histories that are quite distant from the resources they interpret. The publication of "Situated Cognition" by Brown, Collins, and Duguid (1989) in the front–piece journal of AERA is emblematic of how "situatedness" has come to educational studies more recently through the lens of cognitive and computer science, though it owns an entirely different, even oppositional intellectual history. My commentary is on the question of how else it might be understood and what (else) we might want from it in matters of educational study, in the particulars of Jim's treatment of our corpus of study materials.

The issue is not one of a "registry" for ideas, but of analytic communities and cultures. The "situated perspective" is not only an unfinished commentary on the meaningful order of ordinary worlds, it's a commentary on what the study of such worlds might look like, and yield. In the end, "the situated approach" may offer to educational studies an entirely different, analytically incommensurate program of inquiry, complete with different aims, tasks, questions, measures of adequacy and, summarily, ambitions than our more familiar understandings of educational research. Holy grails may work very differently in each, and while no one can say inclusively just what the "situated perspective" is or how it should be read, from an ethnomethodological perspective a couple of things can be said that may be useful for what follows.

First is that it is a descriptive analytic program. There's much to be said in the philosophy of social science about the logics of explanation (and how the promise of causal links premises a social world organized that way) and those of description (cf., Dewey, 1929; Quine, 1960; Winch, 1990; Wittgenstein, 1958). My argument is more modest. It is only that if we posit a world of situated action, then we posit a competent world of social action. Competence is a delicate and/or garrulous term in the contemporary literature; endless competencies are implicated in the notion of "knowledge domains." But the competence I refer to here is a competence in, to, and as of interaction, or speaking and acting competently in concert. This competence is arguably the first one on the scene, and the first curriculum of childhood. We (professional analysts) encounter worlds already in place, already competent to their affairs, including the competence to teach and learn them. We can then speak of situated action and what is orderly about it as competent practice, wherein meaning – and thus order – is achieved by disciplined ways of speaking, listening and acting. Those practices – situated practices – are roughly what the phrase "ethnomethodology" points to and recommends for study. They are, in my view, what the situated perspective recommends for study.

If so, and second, the notion of situated action points in the general direction of a grammar of action, or how meaningful action is assembled in real time and thus sequentially. Conversation, or talk–in–interaction, is the emblematic domain. It is, in Sacks' phrase, "non–disorderable": Utterances, turns, and sequences of them cannot be put together just any which way and make sense. Among a few of the things that sequential analysis has shown us in remarkable detail is how it is that conversation – and all that conversation achieves, including its "contents" – is then an analytic organization. The "analyses" here aren't those of professionals, but rather of cultural members; to be a competent member is to be an analyst of ones own talk and the talk of others (Garfinkel & Sacks, 1970). As one example, consider the ways in which a teacher's pause in next turn to a student's reply is routinely analyzed by everyone in the room as the portent of a disagreement or failed answer, and how things like pauses are produced in concert by everyone who witnesses them.[1] Or how the question "Are you doing anything tonight?" can be heard for a pending invitation in third turn and answered so as to make such an invitation relevant or not. Endless – genuinely endless – and sustained analyses of just these kinds constitute the orderly production of conversation as social action's most massive domain. To speak of "situated action" is to build descriptions of those first organizations on the scene.[2]

Such grammars of action are not "codes" played out on docile fields. They are rather the ordered productions of sensible fields, fields within which things like the "contents" of interaction – including informational contents – are assembled. They are enactments, in situ, and if this is the situated perspective we entertain, there are some further things that follow as matters of an analytic program fitted to it.

As suggested, it would be descriptive, local and ethnographic in its habits. To see how an activity is assembled is to describe it closely in terms of its endogenous production. By "endogenous" I mean that the descriptive language would be leveraged from the very affairs it describes. Classroom lessons, for example, show the activities of pointing, reciting, asking questions, answering them, deferring them, observing the answers of others, etc., all ordinary activities and common practices. That lessons – even sophisticated lessons – are built from them as situated enactments means that lessons *already* possess the terms of their description: their descriptions are none other than an account of their productions, a descriptive–analytic account of an assemblage–in–action.

Relatedly, the fields of activity that yield such things as classroom lessons would stand to what the lesson comes to not as a weighted set of causative structures or variables, but as the natural histories of grammatical productions. The analytic field is entirely different than what we imagine for process–product or central tendency models. Empirical in its insistence on cases–in–detail, the study of situated action warrants its findings in actual cases, and their reproducibility in next cases, rather than on empiricist accounts of tendencies in the aggregate that are unavailable in any actual case. (See Coulter, 1983 on the difference.) The study of cases *in situ* stands at some distance from an analysis of variables in the aggregate, or an understanding of social worlds organized that way.

Thus, in Garfinkel's parlance, the situated perspective stands as an alternate form of analysis, alternate to "formal analysis," meaning by the phrase the familiar professional analytic tasks of crafting formal representations and arranging them within fields of principled and/or mathematical relations suitable for theorizing causatives, efficiencies or optimal design dimensions. He sums those tasks as tasks of "generic representational theorizing" (Garfinkel, 2002), and one needn't affirm his critique to recognize the description. [3]

The situated perspective points then not only to an account of ordinary organizational things in everyday worlds; it has implications for how we would proceed to take interest in them, what we would do with those organizational things analytically, or methodologically, or even scientifically. But in my reading of Jim's paper, he has recruited the situated perspective to a project that seems largely unchanged by the recruitment. The analytic program – a program of theorizing formal structures, hypothesizing their relations, and measuring the conjectures to the aims of general theory – is virtually unchanged. The project seems to be one of assimilation, instead, assimilating the notion of a "situated perspective" to the very tasks whose critique leveraged the innovation. We see it in various places in the paper and especially in some of its most concise programmatic formulations. I want to take up just a few of them, before turning to how else we might take interest in the corpus materials.

A Formal Analysis

I want to begin with a central formulation in the very first paragraph of the position paper. It speaks to the aims of the paper and to a much larger program: "to contribute to the development of a theory of cognition and learning in interaction." The formulation rings with intellectual history: two of the canonical topics of educational research, one dating to the first half of the twentieth century (learning theory) and the other to the second half (cognitive science) are joined to a very different and distant intellectual estate, interaction. Jim immediately sketches what would then be ideally achieved by it:

> . . . a theory that explains dynamic aspects of interpersonal interaction with the same degree of rigor and specificity that are achieved by sociolinguistic accounts, and explains the informational contents of interactions with the same degree of rigor and specificity of information–processing accounts. (p. 41)

It is quite clear that in the measure, interactional accounts (the phrase "interpersonal interaction" seems redundant) will be disciplined to the rigors of a very different analytic discourse, just as it is clear that they are, by this account, not so disciplined now.

In this first passage and elsewhere, there are recurrent binaries that organize the developing theoretical model. "Binaries" have become something of a code elsewhere in the literature, presaging a deconstructive exercise. But it's not that things might not come two–by–two. The question is rather how we understand their genealogical and analytic relations. In the particulars here we begin from the informational and the interpersonal.[4] They become differentiated and amended as the paper develops, yielding the semantic and the systemic, and come to stand on behalf of the cognitive–informational and the social–situated more generally. I want to briefly track the transformations and how they come to rest.

Though the paper allows that the more familiar cognitive programs that preserve the central place of individual cognition are feasible, Greeno is clearly proposing something different:

> Instead, I am appropriating concepts and representations that have been developed in individual cognitive science and psychology and reinterpreting them as aspects of interaction in activity systems and social practice. (p. 43)

The passage can be fairly read as saying that the concepts developed from individual cognitive science are derivative of action, interaction, and social practices, insofar as they are "aspects" of them. This would be an agreeable reading in my view, consistent with recent studies and criticisms of the cognitive metaphor that see it substantially as a move within a natural language game. By those arguments, "mind" is very much an "aspect" of interaction; we find it as ways of speaking, grammars of language–in–use, taught and learned along with their occasions. When we say "I have a penny in my pocket" a world is attached wherein pennies are substantial things that can be located, collected, examined, tracked, and compared. We tend to hear the phrase "I have an idea" in a similar fashion, establishing, as of our natural language use, the "materiality" of thinking and the things thought and assigning them a place (cf., Costall & Leudar, 1996; Coulter, 1989, 1991; Coulter & Sharrock, 2007; Edwards & Potter, 1992 for different readings of the critique of cognitivism; the "penny" exemplar is borrowed from Hacker, 1999). On this account, interaction is the constitutive field of the cognitive discourse, and though Greeno says further that his project "aspires to a theory that is primarily about interaction in activity systems" (p. 43), I think he subsequently thinks better of it. In the end, the appropriation seems to work from the other side: Concepts are appropriated from the situated perspective and rendered as aspects of interpersonal systemics and informational semantics (see his p. 43).

In an early aside, the distinction between the "informational" and the "interpersonal" becomes that between the "semantic" and the "systemic,"

> where semantic aspects involve the referential meanings of concepts and assertions that are made and relied on in activity, and systemic aspects involve the interactive processes of that activity. (endnote 4, pp. 67–68)

The passage sketches a venerable organizational divide where we have meaningful contents on the one side, and structure–without–contents on the other. These become the central poles of the model, and sensible action then becomes the product of the two. This in turn becomes the analytic task and puzzle: to work out their articulation in a formal way. The semantic comes to include things like cognitive schema and information representations, and the systemic–interactional largely becomes the infrastructure or mechanism that sets information, schemata and cognition in play, in activity.

The analysis develops at a steady pace, working from the outline of "levels of analysis of cognition in activity" laid out in Table 3.1, turning to an extended review of prior classroom studies, and then coming to rest with the Wisconsin Fast Plants® materials. Each discussion leads to modifications and elaborations of the model, and further conjectures or hypotheses.[5] There is great order to the development, on the one hand, and yet a sense of the ad hoc, on the other. Adjustments and elaborations are made as the materials are taken up, and the impression is left that there might be no end to it. The modifications seem to follow not only from the weight of the materials, but from a certain analytic discomfort that shows itself early on.

We can see in the same endnote Jim's dissatisfaction with the very structure of pairs that he's working from; they seem to run afoul of his sense of the unity of social practices. The pairing of "task organization and interactional organization" (proposed in Eric Bredo's commentary) doesn't seem quite right: "In my view tasks *are* social. What constitutes a task and which tasks are important for one to participate in are aspects of social practice" (endnote 4, pp. 67–68, emphasis added). The endnote discusses the alternative pairings of "the task and the social," the "informational and the interpersonal," and settles on the "semantic and systemic." As it develops, the model keeps all of them in play, doubts notwithstanding. What is not clear is how any of them, for example, the semantic and the systemic, is any more relieved of the dissatisfaction than the others, if indeed, as the situative perspective would have it, social practices are coherent things rather than paired structures. In light of the expressed dissatisfaction with these pairings, there must be other, analytically compelling reasons for preserving them. My best reading is that they are required by the exercise of crafting a formal model; models have their systemic requirements too.

Each pairing is a variation on a central, even cultural, alternation, variously expressed as the inside and the outside, form and content, process and product. Each shows an alternating structure that delivers the task of re–joining the identities that have been formally separated. The formal model stipulates the divide, and then writes the project of repairing the schism thereby created:

> I hope that the analyses I review and present here are contributing to a more integrated theory that includes accounts of information structures that are the contents of interaction and the interactional processes in which those structures are generated. (p. 43)

The task thus becomes one of healing the rift that underwrites the model. But the first task entails setting in place the formal divisions that require such a project, and one can also see that work in the passage. The proposal borrows from the situative perspective the notion that situated action – interaction – is the generative site of meaning, but casts meaning as "information structures." What then holds the informational–interactional pair together across these several formulations is the notion of a larger "activity system." We see it early on, on page 43: "[The] research that I find promising involves considering information processing as an aspect of interaction in activity systems."

The aim seems very close to a theory of action, and though it doesn't receive too much development, the larger rubric of activity systems seems to house both fields, the systemic and the semantic. It also includes the great bane of every attempt to drill any particular action down into its foundational contents: "background knowledge." Background knowledge has been variously handled in social science as normative expectations, culture, context, and "what anyone knows," and Jim takes it up as the "common ground" of activity. The emphasis is placed on the "vastness" of its material contents, whose contents become the home for "a more inclusive version of the cognitive idea of schemata" (p. 44). He continues:

> To explain these constructions of meaning, we hypothesized several kind of schemata in the students' prior common ground, including general schemata involving participation in conversational interaction, more specific schemata involving accomplishment of school–like tasks, schemata about the operation of physical systems, and schemata about numbers and arithmetic operations. (p. 45)

Presumably, only the constraints of space limit the list. Garfinkel (1967) takes up the related question of how "shared agreement" (the construction of meaning–in–common) is achieved in ordinary worlds, and proceeds in a very different fashion:

> "Shared agreement" refers to various social methods for accomplishing the member's recognition that something was said–according–to–a–rule and not the demonstrable matching of substantive matters. The appropriate image of a common understanding is therefore an operation rather than a common intersection of overlapping sets. (p. 30)

Moerman and Sacks (1971/1988) similarly address common understanding in natural conversation: Turn taking itself – the production of an appropriate next turn, on time – is the first evidence of understanding on the scene, whose organizations are devoted to securing understanding's recurrent achievement. Common ground, on these accounts, has a praxeological foundation and fabric; it is an activity rather than a template, a competent practice rather than an (schematic) inventory of contents.

Interaction as Social Psychology

In some way, in Jim's account, it is in activity systems that informational semantics and interactional systemics find order and integration. And they do so, it seems, in the company of a certain re–casting of the "interactional." By the situated perspective as I know it, interaction and meaning (or content) are joined quite closely at the hip. One could say that meaning is produced–in–interaction, in situated action, in a reflexive–production relationship (as in the meaning of a pause, whose meaning is leveraged by all who co-produce it). But the developing model here relieves the interactional of that work and relationship. Meaning is the province of semantics, represented as information; interaction is the province of systemics, variously represented as "process."[6] Relieved of production work, interaction is then taken in two different directions. In the first and more direct one, interaction becomes a social psychology of "participation," expressed as the "differences between individuals in their engagement in tasks . . . [and] as different ways in which individuals are positioned in their participation" (p. 43). Developed through subsequent notions of participation structure and agency, in my reading this participatory domain figures at least as centrally, if not more centrally, than the informational in the classroom analyses that follow.

We see it set to use later, when the notion of "the *positioning* of individuals in the participation structure of their classroom activity" (p. 45, emphasis added) is introduced. "Participation structure" is a well known and productive formulation dating to early classroom studies by Erickson (1977), Mehan (1979), and Phillips (1972), among many others. In my view, however, it became less compelling for how it tends to leave the impression of a kind of autonomous structure that persons "fall into," as though the structure *itself* possessed agency. By my reading of the situative perspective, such structures are instead glosses or accounts of situated action, a way of speaking of situated enactments. Indeed, the order of the classroom with all its endless familiarity and regularity – including formal, institutional structure – shows its situated accomplishment every time. As Payne and Hustler (1980) remark: "On each and every occasion of a lesson a teacher has to accomplish the order of that occasion. The order of any lesson is an occasioned order, contingent in its accomplishment, 'there and then', every time" (1980, p. 50). If so, we can wonder whose work is being referenced in the verb form "positioning." In subsequent discussions of agency, authority and accountability, one can be left with the impression that these too are formal attributes or substantive "qualities" that can be weighed and parsed to enhance instruction and learning, perhaps even as design dimensions for activity structures themselves.[7]

As the paper turns to actual classroom materials rather than the work of model building, the interactional is formulated in terms of the central binary of the semantic and the systemic. That is, rather than constituting different domains or principles, the semantic and systemic become adjectives of interaction, and this is not surprising: If one is committed to the situated perspective and thus to naturalistic inquiry, interaction–not formal structures–is what one sees and finds.

The model then speaks of systemic and semantic principles of participation, the former having to do with social positioning, as one might expect, and the other, also a matter of relationship, but now "in relation [to] the concepts and methods of mathematics" (p. 47). The semantic becomes tied to Pickering's (1995) "conceptual agency," and subsequently becomes split again to distinguish "between two types of conceptual agency" (agency for problematizing and agency for reconciling). In the process, and perhaps unnoticed, "interaction" has been metaphorized: We have moved from *persons* interacting – human social interaction, or conversational interaction – to the "interaction" of agency and concept. We can understand the use of "interaction" perfectly well in both cases, but we may want to be clear that we are speaking in entirely different registers across them.

A review of prior studies leverages these conceptual developments. Prior studies also offer a comparative context for the discussion of the Fast Plants materials that are our common focus. And when speaking comparatively, it falls substantially to the social psychological aspects of the model to differentiate between the study settings, as in how it is that "the main difference was in the authority and accountability of students in these (Fast Plants) episodes, compared to the classrooms that we analyzed previously" (p. 55), how in the Fast Plant materials "an adult provided the authority needed to decide between the alternatives that were presented" (p. 55), and how, in the conclusion, we are advised to theoretically "differentiate the concepts of authority and accountability in the positioning of students, to include what students are authorized and accountable for" (p. 66). But note how this last recommendation – what are they authorized and accountable for – promises a list.

The situated perspective as I understand it points to fields of practical action and sequential coherence, *in situ*. The descriptions projected by each are likely to be very different.

The Fast Plants materials yield further conceptual elaborations and clarifications, as in the distinction between "problematizing" and "resolving" as "two aspects of discourse at level 3" (p. 54; also see Table 3.1). The earlier discussion of these two principles as "inherently interactive" (p. 49) is difficult to assess. Insofar as they are social activities in the world, yes, they are inherently interactional, not owing to any particular principle of formal logic, but rather because *all* such work in the world is social, situated and thus interactional. But perhaps what is meant is [again] *not* that "problematizing" and "reconciling" are interactive *qua* tasks of human social interaction. It is rather that they are formally, conceptually, structurally, *one to the other* "interactive." The "interaction" here would have nothing to do with social action at all, but is rather a familiar usage from formal analysis: how one variable, concept, principle, etc. "interacts" with another. The relations are entirely formal–conceptual. But in that case, to "hypothesize that... successful reasoning include[s] detecting inconsistencies in the current information structure [the work of 'problematizing']..." (p. 48) isn't a hypothesis at all. It is simply part of what we *mean* by "successful reason." The hypothesis does no more than take up an activity – problematizing – that belongs to a class of activities called successful reasoning, and then conjecture that we might find the former in the presence of the latter. It is unclear what leverage such formulations offer, for either the model's development, or the analysis of actual classroom materials.

In various places this other "formal interaction" shows up, though it's the "real" one – the social–situated one – that the model promises to develop. To say that abstractions like problematizing and reconciling are "interactive" is to offer no more than a clarification of a usage that was owned at the outset; "reconciling" implicates something *to be* reconciled. We need only the words, and nothing of the world, to speak this way. The larger question from a situated perspective might be whether and how speaking this way furthers our description or understanding of "problematizing" or "reconciling" (or "semantics" or "systemics") as actual work in the world on any actual occasion.[8]

Of Holy Grails

Thus, alongside a largely social–psychological account of interaction in the classroom, "interaction" is also set to use as a term of art within the modeling exercise itself. It is the question of how the model's parts will interact, as in the interaction between the informational and the social psychological. It is the central problematic for the model, as clearly seen in Jim's forthright formulation of its "holy grail":

> The holy grail for this quest takes the form of analyses of interaction that require systemic principles of participation in activity systems and semantic principles of meaning and information *in combination* to explain significant aspects of activity. (p. 47, emphasis added)

Two things are clear: the grail is about explaining activity via analyses of the combinatorial interaction of two principles. Social interaction in real time (social action) will be understood only when a *prior* interactions between formal–analytic principles have been understood, and their symmetries revealed. There is also an equity play here, having to do with the informational and the interactional (or the cognitive and the social, the semantic and the systemic). In bringing together these disparate analytic cultures, we could say the question becomes "who takes the lead?" Turning directly to that question – what *kind* of combination they will show – he explains:

> I expect we will find it most productive to consider activity to be jointly systemic and semantic "all the way down," so that whatever the size of an event we choose to analyze, the appropriate analysis will include principles of both informational and interpersonal interaction that function at that gain size in order to explain the event. (p. 48)

There's much to be said across these formulations, about the promise of explanation, the analytic symmetry of the principles, and also the formulation of "informational interaction." We understand the promise of explanation well enough in the culture of science. That the situated perspective is being hitched to it may be the deepest innovation that Jim is proposing; explanation is not the kind of work studies of situated action normally do, or can do, in my view.

The innovation here is really to return us – and the situated perspective – to the normative analytic culture whose critique leveraged the insights of situated action from the beginning. Central to the innovation was the argument that there is no deficit of order in the "plenum" of ordinary worlds (Garfinkel, 1996, *passim*). We needn't import exotic analytic engines in order to understand ordinary worlds; as of their on–going interactional production, they *already* own the terms of their analytic description. And it is description, rather than explanation, that will show us the order of these affairs. (As Ryle [1949] observed, fires have causes; people have *reasons*.)

As for "informational interaction," we have a kind of pidgin phrase standing between two language groups.[9] Which "interaction" it is – the naturalistic or the formal–analytic – is again not clear, and may have something to do with how we have same principles organizing both real–worldly events *and* the theorized model that explains them. Congruence is thus assured from the outset. Analytically (and rhetorically) the "all the way down" formulation is quite central to the task of bringing the semantic and systemic into alignment. As further developed in a endnote,

> The assumption that systemic and semantic principles function jointly... is weaker than alternative assumptions that are needed to justify treating either of them as a context for the other. For one of these sets of aspects to function as a context for the other, the two sets of aspects have to be factorable in a way that I believe is empirically unwarranted. (endnote 6, p. 68)

In this passage we glimpse the depth of formal structure – the culture of formal analysis – that is brought to the project, in a couple of ways. That these principles function "jointly" can lead us not to notice that as principles, they have a formal life– presumably in a frictionless theoretical space – prior to the occasions of their joint functioning. The analytic field they inhabit first shows itself as a neo-classical field of "forms" rather than situated occasions.

Second, the standing of the formal pairing of the semantic and systemic – whether weak or strong – then turns on relations of potential factorability. I'm not sure what this means, or what such a demonstration would require and look like, or what kind of world is required to have it. In my view, we would need to think through these *conceptual* relations first, and when we do, the language of factorability may not be the apposite one at all. Instead, a praxeological or "reflexive" relation seems more likely, meaning that "information" – or meaning – is inseparable from its interactional production, in situ. Were it otherwise, we would be stipulating a new domain of *a priories* – "informational *a priories*" – and this would seem to send us in the reverse direction of all that the "situated perspective" and/or the social turn recommends. This perspective does not first parse the world into essential forms or principles, and then puzzle over how they might be functionally re-joined. Meaning is reflexively tied to social practices rather than autonomous structures, and the grail we find here – the task the paper sets for itself – would not seem to be one the situated perspective would recognize, or pursue.

Some Alternative Analyses

On this central question of how the informational (semantic) and the interactional (systemic) articulate, and in preparing the ground for his treatment of the Fast Plant materials, Greeno turns to some prior classroom studies, ". . .to show that the operation of these principles at different levels of analysis are interrelated" (p. 48). This is his chosen task. My inclinations are quite different, and my aim in this commentary is to show how the work of making sense of classroom lessons is not at all a matter of coeval formal structures "linking up" across different levels and doing so "all the way down." To suggest how we might proceed in a very different direction, I want to begin with a brief sequence from the Fast Plants lessons. It points to how else we could understand the informational and the interactional in the detail of what indeed the parties are doing, that is, in the produced coherence of their situated productions.

The sequence is quite preliminary to the lesson and the day's work. We find it near the 3-minute mark of Day 26 (see Excerpt 1 in Appendix B) where the teacher in charge – I think it's Mark – has prepared on poster paper an initial lay–out of the plant data the students had previously measured and recorded, referred to as the "Day 19" data (see Fig. 2.1). The sequence develops from Debbie's question about the display and reveals a misunderstanding that is entirely competent. At issue is how we are to see a data display, and thus how "information" turns on ways of seeing.

As will be seen in the transcript, Debbie sees the display in ways that were not intended, and we can usefully ask how she did that. Committed to naturalistic inquiry as the situated perspective is, in posing the question "How did she do that?" we are not inviting formal hypotheses or conjectures to answer it. Nor do we set out to import formal analytic resources from elsewhere, on grounds that the setting itself, in its situated production, is insufficient to the question. (There are, of course, many *other* questions, e.g., psycho-analytic questions, questions of history or biography for which the setting may not be a sufficient resource for answering. But those aren't *this* question.) Instead, we look to the setting for analytic resources, and immediately find them: We come to understand how she sees the display that way because *her* task is to demonstrate *what* she sees to the others in the room, so as to show the cogency of her questions about it. Explicating her question is not then our task first, it is hers: to instruct the teacher and everyone else in seeing the chart as she does. In the bargain, we're instructed too. The transcript shows Debbie, the teacher, and an unidentified student.[10]

Excerpt 1 [0:02:46–0:03:47]

0:02:46	Debbie:	I don't get it at the top it says F six and then day an then nineteen an then (1.0) data an then=
0:02:53	teacher:	=So this is F six (.) ⌈and it's al:so:: (1.0) high: lights:
0:02:53	student:	⌊( ) F six since day nineteen
		(2.0)
0:02:60	teacher:	So thez are tha two- those- those are tha two experiments tha we combined cause there's rilly no different- uh- bu' you agree that there's no difference between those two? If they'r under tha same light (.) an we put six pieces of fertilizer in each one.
0:03:09	Debbie:	Uhm hmm.
0:03:11	teacher:	So those are tha two experiments tha we're looking at, an its on day: (.) nineteen.
		(1.4)
0:03:16	Debbie:	So: ( ) tha- tha numbers under dday are rilly (.) from F6 an high lighting? (1.0) Cuz there's- numbers under day.
0:03:27	teacher:→	Ths- these aren't tha col- >are you thinkin these are column headings?<
0:03:30	Debbie:	Yeah.
0:03:31	teacher:	They're not column headings. >Ths is<- F6 (.) an: high: lights: (1.0) frum day ninetee:n.
0:03:37	Debbie:→	Oh:, uhkay.
0:03:39	teacher:	an: an thRL:- th- th- th- its all: in millimeters.
0:03:42	Debbie:	Yup.
		(2.6)

```
0:03:45 teacher:     Ya understan- ya understan what yer lookin'
                     at now?
0:03:47 Debbie:      Yeah.
0:03:47 teacher:     Yeah.
```

I want to defer a close treatment of the transcript and the situated, sequential organizations whereby each instructs the other in how to see the chart. My remarks will be general: Mark – the teacher – shows us that he now sees what Debbie sees [0:03:27]. Beginning with her "Oh. . .," Debbie shows that she now sees how else to see the display [0:03:37]. And if we examine the still frame image in Fig. 4.1, I think we can see what the students were seeing from the outset. They may be novices to statistics, but they are something more than novices to reading two–dimensional displays, and what they see makes very good sense.[11]

Borrowing on Gibson's (1979) notion of "affordances," I want to say the chart "invites" or "beckons" what Debbie makes of it. She *sees* a structure of rubrics and affiliating columns beneath them. The first line of text is written (as of its situated production) to afford such a seeing: words are spaced so as to align to "data columns" below them (see Fig. 4.1). And the students see this way because they are *practiced* in seeing this way. Seeing information *is* a practice; there is no alternation from the interactional to the informational. It is not two autonomous structures or processes "in interaction." Whether navigation charts, radiographs, or texts on algebra (Button, 2008; Lynch, 1985; Sharrock & Ikeya, 2000), information becomes "information" *as* the practiced interrogation of a field; information – what we find – is reflexive to the practices for parsing it, and in this very direct sense Debbie's misunderstanding is entirely competent. Indeed, the premise of her explanation to

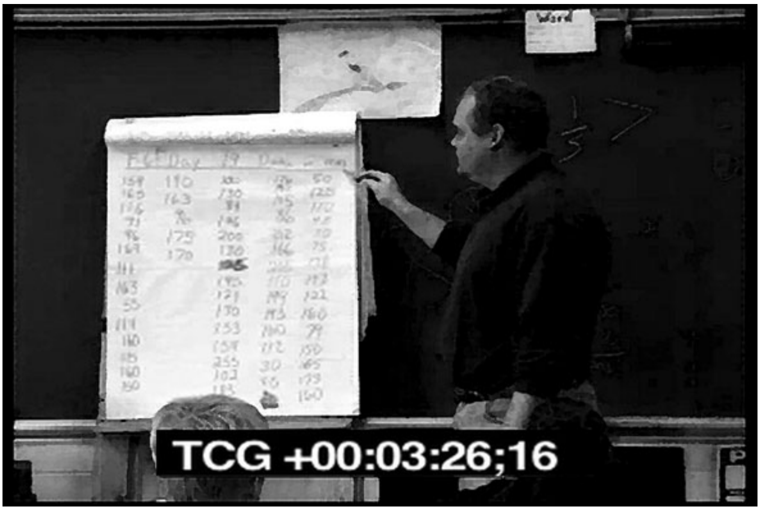

Fig. 4.1 Teacher: "Are you thinking these are column headings?" (Excerpt 1)

Mark and the very possibility that he might see it too is leveraged on the competent practices for seeing they share.[12]

The sequence potentially clarifies the order of relations Jim's paper is seeking, though it shows something quite different from what he finds. Here, the information is constituted *in* the seeing of the display, as a practical, evident seeing that can be taught, learned and also mis–sighted. "Information" thus must have the full complement of a competent community to show itself. Information, in this view, is an achievement or outcome of disciplined practices, as in "how we see a columnar display on the blackboard organized by rubrics, or not," all the way down; it has no prior standing for them or for us. It is a practice, rather than a principle prior to it.

There is a second Fast Plant sequence I want to consider, the one taken up as a "A Lesson in Abstraction" in Jim Greeno's lead paper. It has to do with how the group of Anneke, April, Jewel, and Wally make sense of what Rich – their Teacher – has to say about their initial layout of the plant growth data on graph paper. Roughly, the question becomes whether or not their display needs to identify the individual plants, or whether the "data points" themselves are sufficient as the analytic field. Jim briefly discusses what they, and we, might learn from it:

> For the students, I believe there was a significant opportunity to learn about a semantic issue, selectivity, that is inherent in representation. . . As for a lesson for us analysts: I believe this provides another example of an event for which it is useful to combine semantic principles of information processing and systemic principles of interpersonal interaction to explain what happened. An account of the group's use of ordered numerical intervals requires hypotheses about their knowledge of the number system, the containment of numbers in intervals, and conventions of graphical representation where locations refer to numerical values. . . On the other hand, systemic hypotheses about the students' positionings in the participation structure and commitments to positions in the discussion also seem to be required. (pp. 58–59)

Treated as a "lesson in abstraction" the characterization is quite sensible within its project of seeking the ties between information, abstraction, representation, and interaction via a hypothetical method. The students are not dealing with plants here, but numbers that represent them. They (the numbers) do so as informational displays and representational mobilities. In this way the three cognates – the informational, abstract and representational – come to rest on the students' first, tentative organization of their Day 19 data, and we can then take interest in how they decide what their graph will abstract and selectively represent, as an informational corpus. I want to call this a formal account of "what the students are doing." A similarly formal and hypothetical account can be assembled of the operative principles of interaction.

To them, however, I want to juxtapose a situated account of what they are doing, paying close attention to what, indeed, as matters of their local, situated actions, they do. Rather than relying on propositional logics, I want to build a praxeological account of how they assembled the agreements and understandings that led to what things came to as a material field. By this alternative account, the lesson confronts the students with practical tasks and reckonings having to do with the 63 measures they have made and how they are to arrange their chart to account for and make use of them in a way that acquits their lesson's tasks.

On this account, the display space is less a “representational space” than a practical one, a material field of practical objects and their arrangements. Signs, displays and representations of various kinds (e.g., stop signs, box scores and radar screens) have their palpable, un–mediated presence too, and it seems to be on this kind of field – an evident, material field of objects and relations *in situ* – that the students are working to find and follow their instructions. The transcript is a long one, and rather than presenting all of it, I’ll present segments fitted to the discussion.

The first feature I want to point to is a commonplace of classroom instruction. It is that the sequence unfolds as an organization of the parties to the interaction. Canonically, classroom instruction shows two parties – the teacher and the class – and we see this organization in how the students collaboratively produce single turns, and/or amend and elaborate single utterances with multiple speakers, each replying to Rich as the teacher. The general organization of the talk is an alternation between teacher and students, as seen in the three exchanges below:

Excerpt 5 [0:39:15–0:39:24]

```
0:39:15 RL:        I’m not sure I understand tha, (0.2) tha graph
                   tha’ you made: (0.3) I see it goes up, (0.8)
                   but ⌈(             )
0:39:20 Jewel:         ⌊Okay:. (0.4) What- S’okay, I’ll explain
0:39:23 April:     We’re not done yet.=
0:39:24 Jewel:     =We’re not DONE with our graph yet.
```

Excerpt 5 [0:39:43–0:39:56]

```
0:39:43 RL:                          ⌊So lemme- hep- help me out,
                   by- I’m gonna have- I- I- see: something up
                   there that’s a hundred and twenty one
                   millimeters high. Where does that come in on
                   yer graph. =
0:39:52 April:     =Ah hunerd: ⌈(hundred) an twenty one:
                   (.) right ⌈here.
0:39:52 Jewel:               ⌊Hunerd: an twenty one:
0:39:54 April:               ⌊((also points to place on
                   baseline))
0:39:55 Jewel:     Aroun:d
0:39:56 April:     Around there. =
```

Excerpt 5 [0:40:05–0:40:11]

```
0:40:05 RL:        ⌊Wh- What’s over here?
0:40:06 Jewel:     >We’re gonna have tha< plant num:bers:. Er-
                   like- =
0:40:09 Anneke:     = We think. =
```

0:40:09 Jewel: = plant one, plant two, plant three, plant
four, ⌈plant five ( )
0:40:11 Anneke: ⌊But if it doesn't (really) matter.

The last sequence is of interest for both Jim's analysis and mine, as it is where Anneke first expresses some doubt about the unfolding account of her peers. She says in overlap of Jewel: "But if it doesn't matter . . ." [0:40:11]. In the continuing sequence we can see that it is a remark that goes un-rejoined – there's no uptake. An early transcript suggested that it wasn't heard, but that's a difficult assessment to make. "What the parties didn't hear" is not something we normally have access to, unless they tell us. We could, of course, hypothesize some feature of "position" to account for the non-response. Or we could consult the interactional order of its production.

Organizationally, or interactionally, Anneke's remark is distinctive in a couple of ways. First, we should note that it's not the first "qualifying" remark she makes; earlier [0:40:09] she appends "We think" to Jewel's assertion about "having the plant numbers." She thus builds uncertainty into their collaborative turn, to which Jewel seems undeterred in projecting their course of action [0:40:09]. And it's while Jewel is demonstrating how they are going to proceed ('. . . plant one, plant two. . .') that Anneke overlaps. Part of what is distinctive here is that for the first time in the sequence, a student is addressing her peers, and not Rich. The address is achieved entirely as a matter of its placement in overlap and in the token of disagreement that begins it: "*But* if it doesn't matter." It is within this local, situated environment that no one seems to reply.

Wally speaks next–"Cuz it's gonna look all weird." [0:40:13]–but it is difficult to hear which prior turn his turn is joining. (It may align to Anneke's objection; it may not.) More telling for our difficulty, no one orients to Wally as he speaks. What we can see is that Rich speaks next [0:40:15], starting up without gap or overlap, and replies to Jewel, with a question that becomes a next occasion for Anneke to express her doubts.

Excerpt 5 [0:40:11–0:40:49]

0:40:11 Anneke: But if it doesn't (really) matter.
0:40:13 Wally: Cuz it's gonna look all wierd. =
0:40:15 RL: = Oh you're gonna hav:e, um so you're gonna
have sixty three different (0.5)
⌈plants: here. =
0:40:19 Jewel: ⌊Plants.
0:40:20 Jewel: = Yeah. =
0:40:20 Anneke:→ = Does it matter? With tha- (things are).
You're trying to figure out those: (.) tha:
two answers. And it doesn't matter what tha
names of forty-six. the plants are: in those.
So couldn't you just put (.) data from (.)
like Day Nineteen? Couldn't you do that? =
0:40:35 Jewel: = You hafta ⌈organize your data.
0:40:35 RL: ⌊Sure, you can do anything

```
                         ⌈you want (            )
0:40:36 April:           ⌊But then, but then, if you get it right here,
                         (1.1)
0:40:39 Anneke:          Well if it doesn't matter. Cuz you know
                         there's a plant there and you know: that (.)
                         okay, you know there's a plant there, and
                         >then say there's another plant,< same height
                         right there, and then:, you keep going on with
                         ⌈your data.
```

We could say Anneke was "fishing" in her first two remarks ([0:40:09] and [0:40:11]), seeing what uptake she might find, and from whom. Finding none, she repeats her remark as a question [0:40:20], and answers it herself in her extended turn: Given the two questions they're trying to answer, the names of the plants don't matter. She seems to be addressing Jewel, for how the formulation excludes herself: "*You're* trying to figure out. . ." But she looks directly at Rich in posing her closing question: "Couldn't you do that?" In next turn, however, and without gap or overlap, Jewel seems to counter Anneke's proposal, giving a rationale for proceeding as she (Jewel) has suggested, and April [0:40:36] seems to begin a counter too, that ends with a 1.1s pause following her unfinished turn. To them both, Anneke again asserts that it "doesn't matter," and tells them why, and we now have the direct expression of a disagreement [0:40:39]. As for Rich, he seems to ply a studied neutrality. To Anneke's direct question in line 53, "Couldn't you do that?," he quietly replies in overlap of Jewel, "Sure, you can do anything you want . . ." [0:40:35].

Working from Anneke's first embedded remark [0:40:09], we can see how the sequence develops as a different order of speaking from how it began. The students end up speaking to each other, and the difference is quite central to how the group is led to think about their chart – we could say, if we like, how "different information" became relevant. But it arrives not as an informational or semantic organization, but an *interactional* one. We have the developing interactional organization of a disagreement, wherein the matters talked about are inseparable from *how* they are talked about. In my view, neither statistics, abstraction, representation nor information, as professional–conceptual registers, has any purchase on the students' vernacular task as they – and we – find it here. Those registers – the formal ones – are themselves ways of speaking, and in their familiar analytic deployments, they displace our hearing of how the *parties* are speaking. The situated perspective, however, tends to hold its interests in what and how the participants are doing, whatever they are doing.

Anneke [0:40:20] is working from their two assigned questions (she turns and looks to the board when she references them), and it's a lovely question to ask how, as a matter of the interrogation of a question whose answer we don't know, we come to see the puzzle parts we may already possess, and which of them may be the most relevant ones. Their task at this juncture may have far more in common with solving other kinds of bricolage puzzles, like murder mysteries, board games, or the puzzles of following instructions per se (see Amerine & Bilmes, 1988), than with domain knowledge or hypothetical information structures. It is for them first and foremost a practical task, rather than a theoretical or disciplinary one. They have to *do* something with all these numbers.

Before considering their disagreement and what becomes of it further, I want to make mention of what is sensible, reasonable, and competent about how the students have gone about representing their work so far. It's a difficult assessment to make insofar as we can't actually see the chart in the visual record. But we can note a few things from their talk about it. First is that the students have laid out the grid in a way consistent with their training and understanding of the task. They understand it as an organizational task and they have apparently produced an inclusive organization of the prior week's work. The chart has its axis–orientational properties, and they thoughtfully answer Rich's early questions about placements and procedures for using it. In various places they invoke their competence as resources to their accounts, as when Anneke explains what the "Xs" mean [0:39:39], or Jewel rejoins Anneke that "You hafta organize your data" [0:40:35], or April speaks on behalf of "how a line graph normally is" [0:41:15]. These are among the evidences of their learning so far.

We can also note, following Leona's "reflection notes" on her instructional work with the students, that the graph paper is already a coherent field. Mindful of our first sequence, the graph paper already has its affordances for finding and seeing organizations. As she says: "The graph paper, coming in close conjunction with the recent graphs of the wicking, may have pushed some of the kids in that direction." I want to say it "invited" them to produce and enact competencies that their lessons had already taught them. Those competencies are resources to their learning, and as the sequence unfolds the students *do* come to see their task – and how to organize the chart in a way that is responsive to it – differently. We are agreed on that. What I want to note about the transformation is that it follows from their practical, even vernacular operations on a material field, for which Rich is substantially responsible for putting the field in play. He does so in a couple of ways.

One entails leveraging the developing disagreement between Anneke and the others. Disagreements are witnessable things, and it is in the transformation of interactional organizations that a "change of minds" begins to show itself. We've followed it through Anneke's turn, where she pegs their task to "figuring out those two answers" [0:40:20], and to the explicit disagreement that emerges between her, April and Jewel [0:40:35–0:40:38]. Following Rich's initial neutrality, he now–in overlap of Wally–takes the turn space for a reply to Anneke's extended turn [0:40:39], and returns to Jewel's first counting of the plants [0:40:50]. There's a lovely ambiguity in his offer to "answer your question." Whose question? April's unfinished one [0:40:36], Anneke's pointed ones [0:40:20], or "the question of their disagreement?" We can note that when Rich thus returns to the counting of the plants, it is April and Jewel who respond and confirm that he's doing it as they proposed at the outset [0:41:04–0:41:05].

And *then*, with their disagreement in hand, he returns to, repeats and thus warrants Anneke's question: "How does it help you answer your question?" [0:41:05]. In returning to it, and in addressing April and Jewel, he weighs in on the disagreement. This is not a matter of "information," but of hearing interactional alignments and horizons: *That* he aligns with Anneke's disagreement is a central resource for the others to hear Anneke's remarks as something to which they might want to consider further, which they do: They turn the task to one that will be measured to their questions. They agree to the good sense of "seeing that way."

Excerpt 5 [0:40:39–0:41:15]

```
0:40:39 Anneke:     Well if it doesn't matter. Cuz you know
                    there's a plant there and you know: that (.)
                    okay, you know there's a plant there, and
                    >then say there's another plant,< same height
                    right there, and then:, you keep going on with
                    ⌈your data.
0:40:49 Wally:      ⌊(Did you take those off of ⌈there)?
0:40:50 RL:    →                                ⌊(Okay let me)
                    answer your question. Like let's say tha first
                    plant (.) I'll call it Plant One, and I look
                    over I'm going to call one hundred and fifty
                    nine, Plant One. And then I look over there:
                    and I see: a one hundred and sixty-five,
                    that's Plant Two?
0:41:04 April:      Yeah.
                    (1.0)
0:41:05 Jewel:      Yeah.
0:41:05 RL:    →    How does it help you: answer your question,
                    (1.0)
0:41:08 Jewel:      Well but ⌈you said-
0:41:09 RL:                  ⌊if I call one Plant One and the
                    other Plant Two?
0:41:13 April:→     It doesn't.
                    (0.7)
0:41:13 RL:    →    It doesn't.
```

Were we to leave it at this – as a matter of disagreements and their alignments – we might have an unremarkable social–psychological account: Rich, as an "opinion leader," transferred "capital" to Anneke's position and gave the others reason to think better of it. He "weighed in" on the issue, and for all sorts of reasons he "weighed" the most. And indeed, something like that happened. Students do listen when teachers show alignments. But if this were the opening, how Rich then proceeded, and had proceeded from the outset, is an entirely different matter.

This point is tied to my hunch that there is a great deal about the professional practices of classroom teaching in its situated particulars that the instructional literature has yet to describe or begin to take interest in. In the particulars here, I want to say that the very best classroom teachers are very very good at giving "hints," and that this is what Rich is doing throughout; giving hints and building the grounds for pursuing them, where hinting is a practical game of nurturing the conclusions of others. As it is exercised here, hinting yields agreement. It seems to go like this:

From the outset, he frames his comments and questions as difficulties for *his* understanding. He invites their instruction [0:39:15] and the gambit recurs across a series of questions about their subsequent answers and instruction (i.e., [0:39:37] and [0:39:43]). For the students, this entails "giving accounts" and then demonstrating the sense of them by making *use* of the display, where they jointly answer his question of where something "121 millimeters high" would find its place [0:39:52–0:39:56]. They answer with confidence, noting relevant sources of uncertainty and there are a series of questions like that (e.g., [0:39:56], [0:39:60], [0:40:02], [0:40:05]). To each of them they answer, and across each of these question–answer pairs he and they progressively "tame" the field of the paper. That is, they produce-in-interaction a field of locational 'here's and 'there's held in common (see, for example, [0:39:56–0:40:03]). These aren't statistical 'here's and 'there's, nor abstract, nor representational, nor informational ones. They are rather practical locations *on the page*, found in and through their talk about it, that begin to fill in the chart as one they see the same way, point to in the same way, to same places, by similar reckonings, and thus navigate in a same way as thoroughly practical tasks and actions. In their collaborative pointings we see their competence to the topography of the chart, as a topography–in–use. These are among the organizational achievements of their situated actions (see Fig. 4.2).

What they achieve is a stable, navigable field. As an activity, we can call it "pinning down the bed sheet," wherein we begin at one corner – my guess is that pretty much any corner will do – and proceed to the others until the sheet – the chart – is finally in place. Only then can we step back, take a look, and decide whether it's well fitted or not. That's the second piece of Rich's work, contingent on the first. With the sheet in place – I want to shift metaphors and say with the Game Board in place – we can then begin to throw the dice, take our turns and see where we can go. Having gained their assent to his questions, thereby reflexively setting in place this local topography of "heres & theres," what Rich does next is to organize a scenario for its use. As Anneke remarked, "you keep going on with your data" [0:40:39], Rich enacts the same theme: *Can* they "go on" with the layout as they have organized it so far?

Fig. 4.2 Group 2's collaborative point (Excerpt 5)

That is, he asks for and gets confirmation that they intend to have "63 plants here . . ." [0:40:15]. And then, he begins a mock-up of how they would "bring the plants to the chart" [0:40:50]: that they would look for Plant 1, and then look for Plant 2, and he does so as a way of pointing to an iterative sequence – counting by plants – to show, projectably, how it *cannot* proceed. And this is what Jewel sees in her agreement [0:41:04], in next turn to April's, and evidences in her brief protest: "Well, but you said-" [0:41:08]. She and April have discovered a counting game that can't go on *that way*. They see the horizon of moves Rich is pointing to as moves in a pointless game. And they see it in ways having nothing to do with number systems, ordered intervals, or any variant or form of formal logic. It *does* have to do with a local history of moves on the graph paper, but in an entirely practical, rather than disciplinary way. We don't need hypotheses to account for it – hypotheses won't account for it – but descriptions of what, indeed, they are doing, might.[13]

There is more to the sequence, but I want to conclude my treatment here. Rich and the students are not working on an abstract or representational field, but a material one. It is only *as* a material field that his instruction – his methodic questioning, hinting and practical demonstrations that lead to agreement – can work. They are not organizing an abstract formal structure, but a local field of places and reckonings, and are led to the practical activity of "counting" of a kind. Rich organizes it so as to show *in* their answers to his questions a practical topography and what can and can't be done with it. This is what they are led to see, and agree to. Produced and discovered as of their situated interrogations of the field through their work together, what they see is joined at the hip to how they proceed. In every case, information has a praxiological foundation.

There is of course a logic at play here, but one that cannot dispense with the local organizations of these situated enactments. It is not the logic of "information" or "representation," but of local grammars of action that are intimately, reflexively tied to a vernacular field. Working from within this local, situated assemblage, they discover and agree upon a way to proceed, and we can understand how they do so without recourse to binaries that set interaction on the one side, and information, or even cognition, on the other. The contrast to a formal analysis could not be more bright.

Are we witness to the play of formal structures of cognition, abstraction and information here, or to local orders of coherence produced in situated action? It is a very large question, on which a great deal, at least in the professional literature, turns. Wittgenstein (1967) offers a concise formulation of these analytic alternatives – and the pedagogies they own – in the form of a question. Depending on our answer, we will proceed in very different directions. And irrespective of how we answer, we can see an incommensurability between them, and an intimation of deep conceptual difficulties for any proposal to integrate them. The question is this:

> Does a child learn only to talk, or also to think? Does it learn the sense of multiplication *before* – or *after* it learns multiplication? (§ 324)

The questions are turning the same ground, but the second question is more accessible. We can phrase it this way: Does a student learn the sense of statistics as matters of mathematical logic, reason, abstraction, representation, and the rest, *before* or *after* she learns how to put together statistical displays and do things – normal things – with them? Clearly, if the answer is "before," then educational research in its pursuit of "authentic" thinking, domain knowledge, conceptual change, formal reasoning, "thinking like a statistician/scientist/mathematician," etc., is on the right path. Authentic practice is not only at the end of the curriculum, on this account, it must be from the beginning too. This has long been the prevailing wisdom of the literature in its calls for authentic practices all the way down. Among other things, this path has produced a remarkably resilient, and even moral, history of dissatisfactions. It leaves us, as Jim is, less than satisfied with the performance of these students, and perhaps the teacher too. His summary assessment of the Fast Plants sequence concludes:

> On the other hand, the opportunity for conceptual agency was also limited. The concepts were illustrated in the discussion, and students participated in the discussion that included the concepts. However, meanings of the concepts seem to have been drawn out from the students, rather than having been initiated by them. Thus, their agency in understanding was primarily animating, rather than authoring. . . (p. 65)

If, however, the answer to Wittgenstein's question is *after* – that novices of any and every stripe come to understand their practice, whatever it may be, *after* they have learned how to do it – then our entire vision of what these students are engaged in doing is changed, and our interest in and understanding of their pedagogy transformed. We see Rich's work of "materializing the graph" as the work of setting in place a local curricular field in which students can see, produce, point to and remark on alternative schemes of use, having to do with actual, iterable moves within a cogent, situated horizon of moves, and then make assessments of "goodness of fit" to their practical tasks at hand. In this light, the lesson strikes me not only as a nice piece of work by Rich and by them, but an instructive piece of work for us, and for whomever would take interest in learning how to teach the actual, practical, even craft–based mobilities of simple statistical displays.

Conclusion

In a very brief passage, Harold Garfinkel (2002) characterizes ethnomethodology's program as "a program for the reform of technical reason . . ." (p. 93). He doesn't say much more about it. Alternatively, everything he says – and has said – is about it, and it may be a very useful way of thinking about the situated perspective in educational studies.

"Technical reason" would have it that the students are, or should be, engaged in plying the formal, technical categories and cognitive operations of mathematical practice, including things like conceptualization, abstraction, representation, both the direct and indirect varieties, and their cognate formal practices. The project of technical reason underwrites educational research in the twentieth century. It is a cultural program as much as a technical one, promising to write a learning and/or instructional theory that would clear a path from novice to practitioner in formally reproducible terms. It has been the holy grail of educational studies for a very long time.

To “reform” it would be to say that these things look quite different when we take up the ordinary work of the world on actual occasions. This is the central thrust of the situated perspective, and also what contemporary studies of science and the workplace are showing us as well. As Lynch (1993) observes of science studies in particular, when we begin looking closely, “The spectacles of science and technical reason are likely to dissolve into myriad embodied routines and diverse language games, none of which may be uniquely scientific” (p. 316). There is no “devalorization” here. Science is no less scientific for having described its situated productions. So too for each and every professional domain (math, history, writing, etc.).

On the other hand, and substantially moving in the opposite direction, I think the contemporary literature in math and science education is quite determined to write new descriptions of technical reason into the curriculum as the bases for effective instruction and design. In my view, this is the aim of Jim’s paper, what it hopes to achieve, and most especially what it hopes the “situated perspective” will deliver. I take interest in it as a proposal both familiar and novel, innovative, and yet also ambivalent to its own innovations. I find in it the confirmation of a larger impression about the literature in social cognition, that for having discovered the social, it tends to imagine that we can have it on the formal, technical and cognitive terms that the literature already owns. We see it in passages such as the following, where Jim is speaking of the Habitech materials on mouse populations.

> Here we hypothesized ways in which aspects of moment–to–moment interaction can be explained in terms of students’ positioning and their processing of information. (p. 50)

The passage is in hot pursuit of foundations for moment–to–moment interaction, and the foundations (cognitive) are completely familiar.

But we can’t have it both (or any) ways. We can’t have it that it is the interactional–informational pair “all the way down,” or that “information is assumed to be constructed in the interactive process,” or that position is the systemic dimension of interaction, *and then* propose that interaction can be “explained” by positioning and information processing. That which interaction organizes, constructs and/or achieves cannot then stand as interaction’s *explanation*. Note further that what is to be explained is “moment to moment interaction,” as though it were a kind of epiphenomenon. Yet by ethnomethodology’s reading of situated action, at least, the organization of interaction in real time is the generative site of meaning, and thus of order, structure and recurrence. By this account, the description and understanding of moment–to–moment interaction *is* the “situated perspective.” The problem I am pointing to, however, is not so much a logical one, as a dispositional or grammatical one. The troubles I am pointing to are the kinds of infelicities that follow when we aim to integrate incommensurate understandings of how meaningful social worlds work.

The incommensurabilities enforce a choice. In the choice expressed in our position paper, “interaction” becomes a social–cultural coat hanger for the venerable formulations of cognitive science: information, schema, motivation, memory, routines, etc. It becomes the place where these formal structures show themselves in public, and this tends to confirm the sense that it is not the cognitive that is being appropriated to the social, but quite the other way around. As Button (2008) remarks in his review of Hutchins' (1996) discussion of "distributed cognition," we have a move that offers no re–appraisal of the computational model of mind, but rather a demonstration

> that the cultural world can indeed be handled in the very terms of cognitive science. Thus, showing that it is possible to re-describe the world in cognitive terms is to demonstrate the extendibility of cognitive science from descriptions of a supposed inner world, to descriptions of the outer world. (p. 95)

In trying account for how a discourse that affirms a "situated perspective" moves at once in the direction of formal, technical reason, I've come to think of it this way:

A parallel innovation in educational studies in the last 20 years has been the emergence of the metaphors of "knowledge domains" and "apprenticeship." We now understand that literacy, for example, and math and science, have their distinctive knowledge and/or competence domains, and thus to develop curricula and accelerate learning we are advised to consult how the "masters" do it. The advice is not new (see Duschl's [1985] history of science education), though our descriptions of what they do, rendered as formal structures of mature professional practice, are. Holding aside how these renderings may suffer from similar conceptual knots, these moves have yielded what I want to call a kind of "Whig Developmentalism."

The "Whig" here borrows from the formulation "Whig History" by Herbert Butterfield (1931) in his critique of how the history of science, among other histories, is practiced. The sense of the phrase in his context was this:

> The Whig historian stands on the summit of the 20th century and organizes his scheme of history from the point of view of his own day... he will find it easy to say that he has seen the present in the past... when in reality he is in a world of different connotations altogether. (pp. 12–13)

By "Whig Developmentalism," I mean the program wherein we take the measure of what novice students are (or should be) doing by writing our accounts of them in the image of professional practice.[14] This is the "authenticity" discourse, wherein for whatever they are doing in the room, we see into, expect for, and measure their doings to canons of mature practice. We see them alternatively approaching or faltering on the path toward professional, disciplinary understandings and identities. We look for evidences, and then remedies, as though we were "seeing the future in the present," and fail to notice how *they* may live in worlds of "different connotations altogether." Thus the desire, expectation and disappointment when they fail to "think like a mathematician, scientist, writer," etc.

Aside from the fact that contemporary science studies are re–writing our descriptions of mature practice, the risk of Whigishness is that we may substantially *miss* what is cogent and competent about what indeed the novice students *and* their teachers are doing. The alternative understanding I'm suggesting – wherein organizations of common understanding re-specify those of technical reason, and thus teaching and learning – trades on a very different reading of “situatedness” and “situated action.” This reading would lead us to inquire, among other things, into how we assemble and set in place practical, evident, vernacular worlds for children, worlds that are, *as of* their practical accountability, teachable and learnable to those who do not already know them, and that our inquiries into classroom lessons might usefully begin just there.

Such a program surely runs against the grain of the cultural and analytic commitments of the larger research community, against the grain of an explaining science, against as well the culture of theorizing formal structures and crafting new design dimensions from them. But perhaps most unsettling of all, it runs against the identifying appointment of the educational research literature, to design accelerating programs for the teaching and learning of children.

By the reading I am recommending, it is not the children who stand to be instructed by the situated perspective (though they may well be the beneficiaries of the instruction of others). It is rather the *adults* in the room. A pedagogy for *us* follows from these descriptions. By these descriptions we stand to reconsider some of our most familiar ways of seeing and speaking of educational tasks and settings and perhaps clarify some venerable conceptual confusions. My premise is that the close description of a practice is at once a *curriculum* in that practice, and a pedagogy for those who would learn how to do it. Such descriptions may be instructive for the community of professionals who work there, and perhaps also for the research community.

It is not simply that I want to pose an alternative to the understanding of interaction and situated action that we find in this position paper. I also want to point out how it falls victim to the larger program it pursues. The divide between the cognitive–informational and the social–interactional delivers the theoretical problematic that organizes the paper. How to integrate the pair is the grail; integration is the puzzle, whether weak, strong, factorable or not. But it is a puzzle of the analytic program’s own making. For having stipulated to the semantic and the systemic, it has created the problem it intends to fix. All manner of effort and consideration is then devoted to this task, as though it were a task that the world of classrooms in their situated enactments had offered up. It has not. Our understandings of classrooms as places where novices find instruction in the situated productions of their lessons will require a substantially different analytic program and vision. The notion of situated action has much to teach us. But we will lose the instruction if we render it in terms already familiar, already authorized, as though the situated perspective were an under–laborer in the service of certainties already owned.

Notes

1. Pauses are very nice things for making sense of the “essential reflexivity” of practical action that Garfinkel elucidates (1967). Briefly, when witnessing an interactional pause, in all the ways in which such a thing can be meaningful (e.g., following an accusation, a proposal of marriage, an answer in class) we routinely do *not* witness our joint authorship of its production. A silence is anyone’s to end and everyone’s to produce, yet the pause

achieves an objective status, notwithstanding this praxeological organization. The pause as an organizational thing is reflexive to its methodic social production.

2. In a brief passage from his lectures where he is assessing what might be gained from the study of ordinary conversation and what kind of program would be required to handle it, Sacks (1984) speaks of it this way:

   > It is possible that [the] detailed study of small phenomena may give an enormous understanding of the way humans do things and the kinds of objects they use to construct and order their affairs...
   > We would want to name those objects and see how they work, as we know how verbs and adjective and sentences work. Thereby we can come to see how an activity is assembled... What we would be doing, then, is developing another grammar. And grammar, of course, is the model of routinely observable, closely ordered social activities (p. 24)

3. The tradition of formal analysis is of course the tradition of social science. We see something of the exercise in the table titled "Levels of analysis of cognition in activity" (Greeno, Table 3.1) as it outlines the programmatic differences between information theory and the situated perspective over a generically represented career path of developing competence. The coherence of the chart has no need for actual cases; cases in their constitutive detail would only and hopelessly complicate the chart's (generic) articulations. We could say the chart offers a narrative structure of a kind; a kind of telling disengaged from the actual, real–worldly affairs it speaks of. This is no remark on how well it is done; it is done very well, that way.
4. There is also the sociolinguistic in this first formulation. It seems to have no further play in the paper.
5. There are a great many hypotheses in the paper, an analytic–rhetorical form one doesn't often see in the situated perspective. When we seek explanations but have, as the natives do, only the "surfaces" of things to work from, conjecture (hypothesis) is an honored way of proceeding, however much it may lead us away from whatever those surfaces may have to tell us.
6. Though references to how interaction "produces" or "generates" meaning, information or informational structures recur, we don't quite see it in the analyses that follow. Most especially, we don't see the meaning–production or information–production work of interaction *in* the classroom materials.
7. It is one thing to observe how authority was distributed differently in the Fast Plants materials than in other settings (see Greeno, p. 66). One may even prefer one "distribution" over another on moral, professional, political, or cultural grounds. Yet it would seem to be quite another to say that students learn better *because of* one or another form. Attractive as it is, to suggest as much is to return us, by technical degrees, to the notion of "best" instruction, or even best "culture." (See McDermott, 1977 for a convincing reminder of why we may not want to be thinking that way, again.)
8. Though I use the phrase a "situated perspective" in the singular, I hope that it is understood that I mean no single, unifying thing. Quite the contrary, there are many of them, each attached to an analytic community that owns a distinctive understanding of the order of meaningful worlds. The proliferation of "constructivisms" in social science is a recent example of this diversity (see Lynch, 1998).
9. An early passage is emblematic of the delicacies of hybridization: "The situative concepts refer to processes that are hypothesized to occur at the level of activity systems and joint participation in communities of practice" (p. 43). Though the phrases are recognizable, I doubt that anyone writing the literature of situated studies of social action would ever say such a thing. Situated action is not a hypothetical in the first instance, nor an aggregate of processes, nor a discrete level within a structure of levels. It is precisely this kind of formal parsing that the analysis of situated action critiqued and set aside (see Garfinkel & Sacks, 1970).

10. The transcripts presented here have been extracted from the longer and more elaborate excerpts found in Appendix B. For ease of discussion, I have inserted arrows and added some timings. These changes remind us that there is no single, best transcript. No one is ever exhaustive, and all are built to serve analytic interests. For some, this is a theoretical matter. For me, and not unlike the students, it is far more practical.
11. Recent work by Goodwin (1996; 1997; 2003) has given us a series of analyses and demonstrations of how meaning and definite sense and reference are achieved in action. Whereas theories of schemata premise an "internal eye," the information–seeing Goodwin describes is entirely practical and real-worldly, as it is in our sequence. See also Rogoff (1990) on the kinds of skills honed and honored in classroom instruction. The navigation of two–dimensional displays is central among them.
12. Note also how Mark's effort to fix the display by underlining the "heading" to set it apart from the columns only furthers the good sense in which the two are seen as an ordered array (see Fig. 4.1). "Information" is difficult to contain; it dissolves into the grammars that give it shape, as in how an archeologist teaches a student to see a clump of stratified soil *as* information (Goodwin, 1996).
13. Analyses of situated action tend to take interest in "small" things that yield larger organizations of sequential order, structure, and thus meaning. As one small thing, note the 1.0 s pause following April's agreement [0:41:04], prefacing Jewel's agreement [0:41:05]. It marks Jewel's agreement as "compelled." That is, in the duration, Jewel sees and shows that she has no choice *but* to agree to Rich's prior formulation that "that's Plant 2," and what she shows in her agreement is how the iteration it projects makes no sense. It is the central moment in which she discovers that her arguments cannot "go on." She *sees* how this is so across the local spectacle of April's agreement. Note further how she attempts a shift of responsibility for why they would ever have seen things that way, "Well but you said-" [0:41:08]. Her protest can't go on either.
14. One may counter that developmentalism is *of course* "Whiggish" – how *they* become like *us* is precisely the question. But the literature on "authentic practice" tends to write a version of the 17th century homunculus: They were like us all along; they are to be like us from the beginning. The resulting account is steadfastly, and morally, normative and self-referential.

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Chapter 5
Representational Competence: A Commentary on the Greeno Analysis of Classroom Practice

Allan Collins

In his analysis of the classroom videos, Greeno provides a theoretical basis for analyzing classroom interactions. He advances the notion of empowering students by positioning them with the authority, accountability, and competence to problematize issues and reconcile differences among themselves. Greeno frames these ideas in terms of fostering *conceptual agency,* a notion he derives from Pickering (1995). These are ambitious goals for schooling that are important to pursue.

Greeno's analysis of how the authority figures acted to resolve differences among the students with respect to the representation of data points up a fundamental problem in schooling. In general educators do not trust that if we allow students to reconcile their differences, they will come up with the important ideas that the curriculum is designed to teach. It is a delicate balancing act to design teaching and learning, so that it seeds classroom discussions with powerful ideas that designers want students to learn, at the same time that students are empowered to resolve the issues they encounter. I think that has been the goal of Lehrer and Schauble throughout their curriculum design, but inevitably it will always be imperfectly realized. As Greeno suggests, the relation of these issues to the students' identities as learners and thinkers seems to me an essential aspect of any analysis of school and classroom practices. In summary, I think his analysis framework provides an important lens on classroom practice.

Rather than discuss the analysis framework further, I would like to elaborate on an aspect of intellective competence that Greeno's analysis only alludes to indirectly. This is the issue of *representational competence* that diSessa (2002b; diSessa & Cobb, 2004) has written much about and which I have addressed in my writing on epistemic forms and games (Collins & Ferguson, 1993; Morrison & Collins, 1995). This issue sits in the background of Greeno's analysis, but is never in focus. It has more to do with curriculum than with classroom practice, though I would argue, and I think both Lehrer and Schauble would agree, that the teaching of representational competence should lie at the center of classroom practice in math and science.

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Understanding Graphing

What is representational competence and why is it important?[1] In his writing diSessa (2002b; diSessa & Cobb, 2004) refers to meta-representational competence as the ability to create and evaluate representations of phenomena in the world. He first noticed meta-representational competence when his research team asked middle school students to represent the motion of a car that slows down and comes to a stop and then starts up again moving in the same direction. The students became very engaged in this exercise, producing a number of different representations and arguing among themselves as to which was the best representation. After several days, with the students taking the lead under the gentle guidance of the teacher, they settled upon a graphical representation as the best representation of the motion. In this case the teacher seems to have had the wisdom to empower students to both problematize the issue of representation and successfully reconcile their differences, though it took several days to complete the exercise.

In further studies diSessa (2002b) carried out experiments to determine what are the kinds of criteria that students use to evaluate representations. He found evidence for a number of different criteria, including fidelity, intuitiveness, simplicity, consistency, likelihood of misinterpretation, completeness, and aesthetics. Meta-representational competence is an important competence for students to acquire, since it is essential to understanding of math and science. It is by developing sophisticated representations of phenomena that researchers have gained the ability to see the patterns, on which many of our mathematical and scientific insights have been built. I see meta-representational competence as a key aspect of representational competence, but only one critical piece of what mathematicians and scientists must develop to be fluent in representing knowledge.

Graphing is central to representational competence. It was graphing that allowed Galileo to see the systematic relation between the distance a body falls and the change in its velocity. The three sessions in the video are focused on scales and graphing, and so I want to talk a bit about what are some of the central issues in understanding graphing. It is these kinds of issues, along with meta-representational competence, that should underlie the teaching of graphing and more generally representational competence. Producing and interpreting graphs is difficult to learn and yet important to making sense of much of the discourse in a highly technological society about scientific and public policy issues.

There are four kinds of graphs that are commonly used to represent data: bar graphs and line graphs, which come into the discussion in the video, and scatter plots and pie charts, which do not come up. Let me mention some of what is worth learning about these kinds of graphs. Line graphs are particularly good for plotting trends and cycles in time-series data, as did Galileo. They depend upon having continuous scales on both axes. In our discussion of epistemic forms and games (Collins & Ferguson, 1993), we described the strategies for creating two kinds of line graphs: trend analysis and leading-indicator analysis. But line graphs can be used for other purposes and so a curriculum theory about the production and interpretation of line graphs should have many parts. Bar graphs, the target structure in the video lessons, are effective for displaying quantities over a discontinuous set of categories. In the lesson the students created a scale by grouping the plants into size ranges, so that the frequencies of plants in each category were meaningful. The idea of an underlying continuous scale for a bar graph is a difficult representational idea for students to grasp, and so probably only a few students got the idea the teacher was driving at. The task given the students is perhaps not the best place to start building key ideas about graphing, since the students were not positioned to derive the key ideas themselves. I am not sure how a curriculum for graphing should develop systematically to capture the kinds of issues I am discussing here, while developing the kind of representational competence that Greeno is advocating.

Scatter plots and pie charts do not come up in these lessons, although they are commonly used graphing techniques. Pie charts are used when there is some quantity that can be broken down into parts, and the goal is to show the relative size of the different parts. The trouble with pie charts is that it is difficult to compare the size of the different quantities; dividing up a bar chart actually makes it easier to judge relative sizes. Scatter plots are very useful for investigating how two scalable variables interact with each other. They are a very good starting place to discover new patterns between variables, and so are an important tool for scientific inquiry. They probably do not get the emphasis they deserve in the curriculum.

The issues of different scales are only briefly touched upon in the lesson, but the differences between nominal, ordinal, interval and ratio scales, as Stevens (1951) described them, underlie many of the difficulties in understanding graphs.[2] It is particularly common to cut a ratio scale in graphs below the point where values of the data fall, in order to heighten the differences shown, but this can mislead people into thinking that much larger changes are occurring than is warranted. Another common problem in interpreting graphs is when an exponential function is plotted on an equal interval scale. For example if the Dow Jones average is plotted over time on an equal interval scale, as it often is, it looks like the stock market is doing much better in recent years than in the early part of the twentieth century. Exponential functions like the Dow Jones average should be plotted on a log scale, where equal-percentage increases form a straight line, so that systematic comparisons can be made. This example highlights the fact that understanding different kinds of functions (e.g., linear, exponential, asymptotic, growth) is critical to understanding graphing. Representing variability is another important aspect to understanding graphing, which the class in the video was addressing. By plotting variability of plant growth in a bar graph, they could see how a normal function arises naturally.

There are a number of aspects of representational competence that are demonstrated by students in the class. For example, in Excerpt 3 the students show that they understand the relation between the X-axis and the Y-axis and that it is necessary to scale each axis so that all the values will fit along the axis. Their plan is to show the height on day 19 of each of the 63 plants that were grown. But they do not appear to think about the questions posed to them of finding a representation that will address the issues of "typicality" and "spreadoutness." In Excerpt 5 the same group is questioned by one of the researchers (RL) as to how their graph addresses these two issues. They seem confused as to whether their graph is a line graph or a bar graph. RL prompts them to think in terms of grouping plants based on their height, rather than treating all the different plants as separate items along one axis. The boy in the group suggests constructing a stem and leaf plot, and RL encourages him to do that on his own. But in a later conversation RL found the boy had simply listed all the different heights in order, so RL prompted him to group the plants by height, just as with the earlier group. In the end the students resolved on a bar graph where they grouped the plants by height, as RL had suggested. They came to understand "typicality" in terms of the median or mode, and "spreadoutness" in terms of the range of heights.

My comments here are meant to raise the issue of what kinds of representational knowledge may be useful to people in making sense of a complex, technological world. In order to develop representational competence in the context of graphing, there are a number of aspects that students must learn, which are alluded to above: the affordances and constraints of different types of graphs, the nature of different kinds of scales and functions, the notions of central tendency and variability, and meta-representational knowledge. Mathematics education focuses a lot of time and effort on teaching algorithms, which technological artifacts are able to carry out for them. The time might be better spent in helping students build a strong representational competence.

Beyond Graphing

Beyond graphing, there are other critical aspects to developing representational competence. In our work on epistemic forms and games (Collins & Ferguson, 1993; Morrison & Collins, 1995) we have tried to describe an aspect of representational competence that lies beyond graphing. There are three types of representational forms that researchers use to guide their inquiry: structural, functional, and dynamic. The different structural forms include such representations as hierarchies, cross-product tables (e.g., the periodic table), axiom systems, stage models, primitive elements (e.g., chemical elements), cost-benefit analysis, and comparison tables. Similarly there are different functional forms, such as causal chains, form-function analysis, and multi-factor causal models (as in medicine). And there are different dynamic forms, such as system-dynamics models (e.g. Stella), agent models, production systems, and aggregate-behavior models (e.g., StarLogo). All these representational forms have rules and strategies associated with them, which scientists learn to use as they construct representations or models of phenomena. I would argue that these epistemic forms are at the heart of scientific inquiry (Collins & Ferguson, 1993).

I can illustrate how epistemic forms provide target structures for representing knowledge with a couple of examples from our earlier paper (Collins & Ferguson, 1993). Stage models are common in historical analysis, psychological analysis, and analysis of any process that is characterized by a series of states. The simplest stage model is a list constructed with the constraint that the stages follow each other sequentially without overlap. Figure 5.1 shows a more complicated version of a

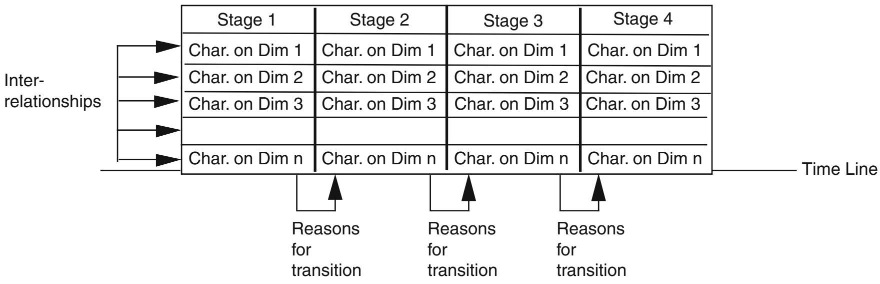

Fig. 5.1 Stage models

stage model. Each stage might be characterized by multiple characteristics, and furthermore these characteristics may be arranged on a set of dimensions (e.g., the boy was angry and tired before his nap, but happy and energetic afterwards). In a more complicated stage model, the interrelationship between the variables might be specified (e.g., energy state determines mood), and the reason for the change from one stage to the next specified (e.g. a nap leads to an increase in energy state). These last four constraints (i.e., multiple characteristics, specified dimensions, specified interrelationships, and reasons for transition) are all optional constraints that a person might or might not use in constructing a stage model.

As a second example, multi-factor models are a common way to analyze causality in systems. They are particularly pervasive in psychology and medicine, but are common in many other disciplines where events are caused by multiple factors. In multi-factor models, variables (called factors or independent variables) are linked together in a tree structure. The branches of the tree are ANDed together if a set of factors are all necessary to produce the desired value on the dependent variable. They are ORed together if any of the factors are sufficient to produce the desired value on the dependent variable. Figure 5.2 from an earlier paper shows an AND/OR

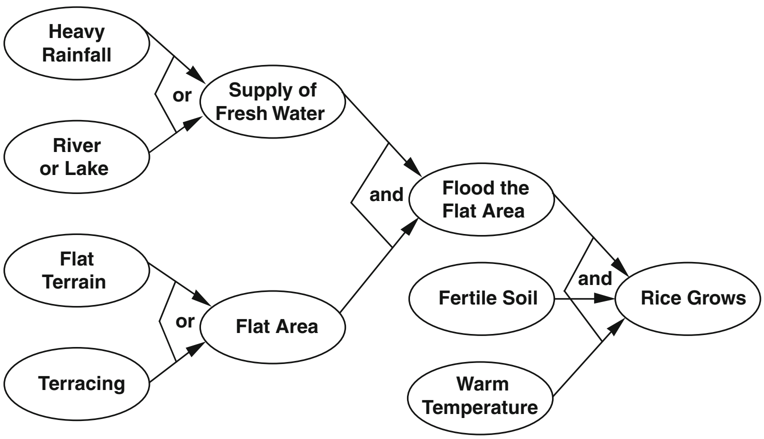

Fig. 5.2 A student's analysis of the causal factors affecting rice growing

graph that one respondent produced as his theory of what determines where rice is grown (Collins, Warnock, Aiello, & Miller, 1975). This epistemic form served as a target structure to guide his construction of this theory.

The epistemic forms and games we have identified (Collins & Ferguson, 1993) are only the most common representational forms used in different sciences. There are many representational forms or model types that are specific to a particular science and new ones are always being invented. System-dynamics models and production-system models are relatively recent inventions, made possible by the development of computers, with their dynamic modeling capabilities. If learners develop the capabilities to produce, manipulate, and interpret these different representational forms, they are gaining use of powerful epistemic tools for making sense of the world. Gaining representational competence should be a major goal of all mathematical and scientific education.

Conclusion

The class shown in the video is beginning to learn how to find patterns in the world by constructing graphs. They are learning something important about how representations highlight some properties of the world, at the same time omitting others. When the group gives up plotting each plant separately, they are throwing away data, which one student feels uncomfortable about. But at the same time by plotting data on a scale, they are seeing how a normal function arises with data points aggregating around a central tendency and are beginning to learn how to predict future distributions. Hence they may be getting a glimpse of the power of representations to reveal patterns that are not obvious in the world.

Greeno emphasizes in his commentary that gaining intellective competence, and hence representational competence, requires granting students authority and accountability. As Greeno (personal communication) commented further about student learning: "If properties of graphs are learned with the kind of agency that was supported in the diSessa classroom . . ., they'll have more of what Pickering called conceptual agency in their learning, and I would guess, be better prepared to use the representational forms with conceptual agency after they've learned them (i.e., be able to figure out what versions are good for different problems, interpret the information in variants of the form, etc.). And related to the notion of intellective identities, they would have been positioned with more authority and accountability in their learning, and (I would hypothesize) this would contribute to their being positioned with more authority and accountability regarding the subject-matter domain of mathematical concepts and methods, which is what I think of as the semantic aspect of their mathematical identity." In other words, to teach representational competence effectively we need to create learning environments that give students the "conceptual agency" to build upon their meta-representational competence to resolve the difficult issues around representation.

There is another important role that representation plays in education that comes through in the video. Representations provide a substrate for scientific discourse and argumentation. They make visible different people's ideas and theories in a compact way. When people's ideas and theories are only represented in talk or even in writing, they are much harder to pin down. But a diagrammatic representation provides a specific reference one can point to and argue about. As we develop new technologies for representing knowledge, such as Boxer (diSessa, 2002a), Stella (Mandinach & Cline, 1994), StarLogo (Wilensky & Resnick, 1999), and AgentSheets (Repenning & Sumner, 1995), we are expanding capabilities to formulate our theories in precise terms (Feurzeig & Roberts, 1999). We are, as it were, at a time of representational flowering. Teaching representational competence will become more and more critical for education in the future.

Notes

1. See Sherin (Chapter 11) for a related discussion of representational knowledge.
2. See Confrey (Chapter 19) for a discussion of how the students dealt with the issue of different scales.

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Chapter 6
The Interaction of Content and Control in Group Problem Solving and Learning

Eric Bredo

In his paper, "A Situative Perspective on Cognition and Learning in Interaction" (Chapter 3, this volume), Jim Greeno seeks a theoretical synthesis combining the strengths of theories of cognition drawn from psychology and theories of discourse drawn from sociolinguistics. In what follows I first consider the wider intellectual context of Greeno's paper, then address the solution he proposes for synthesizing these two traditions. I conclude with a discussion of the uses and limitations of his analysis.

Conceptual Difficulties in the Theory of Mind

The central problem Greeno addresses derives from difficulties with conventional conceptions of cognition. In the traditional conception "mind" is treated as analogous to a physical object having an inside and an outside. Thinking or cognition is thought to take place inside the cranium, or inside of the individual, while everything outside the head or the skin is taken to be external to mind. As Richard Snow put it with regard to the traditional trait-based notion of intelligence

> In yesterday's theoretical writing, the interpretation of aptitude differences typically relied on one or another kind of entity theory. Aptitudes were reified as things in the head of the person. They were not things actually – the old phrenology and faculty psychology had been soundly rejected ... but they were the products of things genetic and physiological, and ...were described metaphorically as things in the head. (Snow, 1992)

With the mind inhabiting the inside of the brain or body, social relationships were treated as part of the external environment, like other things outside of the individual, and therefore as categorically different from mind.

The notion that individuals think and that social life is external to thought is consistent with a traditional division of labor between psychology and sociology. Psychologists study thinking, while sociologists study its external environment:

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social interaction and social structure. Conceived in this way each discipline treats the central concerns of the other discipline as separate from its own central concerns. Psychologists treat social life as something people learn about rather than as an activity that is constitutive of mind or thought, while sociologists treat mental processes as different from the "external" social environment that constrains or influences them. Mental and social phenomena remain fundamentally separate, like the inside and outside of a physical object. As Arthur Bentley noted, the human skin is traditional philosophy's "last line of defense" (Bentley, 1954).

This way of thinking is reinforced by other institutions besides academic disciplines. In traditional classrooms, for example, students work separately on their own tasks, experiencing thinking as an individual matter to which social interaction is an external interruption. Traditional psychological experiments similarly study the behavior of subjects who work on the "same" task, social interaction occurring before and after the task begins, but excluded from the core of the study (Newman, Griffin, & Cole, 1989). More generally, individualistic societies like our own also tend to reinforce the experience that individuals think alone while social life is an external environment to thought.

This way of thinking is both commonsensical and the source of a variety of conceptual difficulties (Bredo, 2006). One difficulty is that it tends to confuse socially constructed boundaries with natural boundaries, artificial kinds with natural kinds.[1] If thinking is largely an individual matter at times, and a collegial activity at other times, then an approach that treats it as though it is necessarily and essentially individual will be prone to over-generalizing its findings. Studying only highly controlled settings where individuals face well-defined tasks alone, for example, tends to reinforce the original assumption that thinking is a purely individual matter. Such a psychology is all too likely to confirm its own prejudices and narrow our understanding of human possibilities (McDermott and Hood, 1982; Bruner, 1985).

Theories and methods based on individualistic assumptions also make it difficult to understand collaborative problem-solving. This has been explored in a series of studies that observed what happens when highly-controlled laboratory tasks are transported to less-controlled "everyday" settings (Newman et al., 1989). In one study, for example, the problem of making a cake from a recipe was transferred from controlled conditions where the task was assigned to a single individual to a natural setting where a group of children were asked to do it largely on their own. Under the latter conditions the children created a division of labor, allocating different parts of the problem to different participants in a dynamic fashion. As a result no single child could be observed to be solving *the* problem, yet the group together solved it successfully. But if the problem was solved, yet no one solved it in his or her head, where did the thinking occur that solved it? Evidently the group itself in some sense solved the problem. Of course this is not really a mystery. The same point applies more generally to any complex product, like a computer, where no single individual understands all aspects of the design. Evidently, to understand learning in a way that is applicable to such common events an approach is needed that does not place mind inside of the individual brain.

An important step toward developing such a perspective involved reconceiving mind as a function rather than a thing. If we think of "mind" as an adaptive process then many different physical entities might interact to perform this function. A child seeking to solve a shape-block problem, for example, uses hand, arm, block and cube when trying to see if a given block will fit into a hole. The "system" that solves this problem includes (at least) the child, the block and the cube. It is clear that whatever is inside of the child or the child's head cannot solve the problem alone, although it is a necessary part of the system that does solve the problem.

The shift from an entitative to a functional way of thinking has been important in modern cognitive science, helping to broaden the notion of *what* can think. Newell and Simon's "physical symbol system hypothesis," in particular, suggested that any physical system that can do certain things, such as store and manipulate patterns representing other patterns, and use these patterns to control physical operations on the patterns, can, in principle, "think" (Newell & Simon, 1976). This hypothesis served to justify the notion that computers can think because they have all of the characteristics needed for such a system (which was, of course, modeled on a computer). It also suggested that a system that "thinks" might be distributed rather than compactly present in one place and time, such as when a network of computers that might be located very distantly from one another together "solves" a problem. The notion of distributed cognition was then helpful in understanding how a group or other collectivity might "think," since it suggested that an overall problem might be chopped up and parceled out to many people, with no single individual being responsible for it all.[2]

While a functional approach helped open up the traditional conception of mind, it also raised new difficulties. When the computational metaphor is taken too literally – with human thinking taken as "computation" rather than computation taken as a helpful metaphor of human thought – the model gets confused with the phenomenon it models (Clancey, 1991). More specifically differences in the way a pattern is said to have "meaning" for a computer and the way symbolic expressions gain meaning for human beings tend to be too easily overlooked (Dreyfus, 1979/1972; Winograd & Flores, 1986). In the Newell and Simon formulation, for example, the "meaning" of a symbol pattern is its "interpretation" in the internal machine operations of a computer or equivalent machine. If "2 + 2 = ?" is input the system presumably translates this into machine operations that perform the operation, yielding "4" as the output. The meaning of the same marks for human beings, on the other hand, consists of what they indicate *to others* that a person is likely to do, as revealed by the others' responses (Mead, 1934). In other words it depends on social-interactional habits or conventions. "2 + 2" to a group of people standing beside two motorcycles might suggest that they divide up, two riding on one motorcycle and two on the other. As Jacobson (1960) and Hymes (1974) spent their lives showing, without understanding what an expression is being used to do in a particular situation it's meaning is not properly understood.

What Is Being Synthesized?

Given the limitations of the computational model, Greeno's desire to include sociolinguistic or social-interactional concerns makes good sense. If one can retain the advantages of the functional approach while making it more sensitive to social interactional considerations, a helpful new synthesis might be developed. But just what is Greeno attempting to synthesize? Since this may be somewhat unclear let me consider the issue in a little more detail.

Some ambiguity about aims is introduced when Greeno discusses the two hierarchies or "levels of aggregation" figuring in his work (Table 3.1). To better understand these hierarchies it may help to note that every activity has both a selectional and a sequential structure (Dewey, 1916; Cazden, 1989). To play a tune one needs to select the right note from among alternative possibilities, and play it at the right point in a sequence. Doing the right thing at the right time is vital in every human activity.

As Greeno suggests, each of these aspects of activity is commonly organized in nested fashion. A short sequence of notes composes a phrase in music, a series of phrases form a movement, and a series of movements make up a composition. Sentences are similarly nested, words making up phrases, phrases sentences, and so on. These are examples of one kind of hierarchy, a temporal or sequential hierarchy. On the other hand, notes or words placed in sequence are selected from a set of relevant alternatives, a contrast set, that may, in turn, be part of a larger set. In social interaction, for example, norms tend to regulate which individual or category of individual can legitimately initiate a given action. As a result, there is a second hierarchy based on nested categories or types, such as individuals within groups, groups within organizations, organizations within communities. I believe this distinction between temporally and categorically nested activities is consistent with Greeno's discussion.[3]

One reason for possible confusion, is that Greeno's discussion seems at times to indicate he is attempting to synthesize individual and group levels of analysis, while at other times he states that this is not what he is doing. In fact, Greeno's comments eventually make clear that he is *appropriating* "processes usually hypothesized to occur at" the individual level and applying them to processes usually thought to occur at a collective level (activity systems, communities of practice, etc. [p. 43]). In other words, his approach has nothing to do with relating different levels of social organization, such as synthesizing psychological work focusing on individuals with sociological work focusing on groups, but rather with taking functions usually considered at the individual level and reinterpreting them at the group level.

Just what to call these functions has been a source of difficulty. Greeno initially termed them "semantic" and "systemic" processes, but now describes them as "informational" and "interpersonal" (p. 48). I initially suggested that they might be termed "task" and "social" functions, thereby helping to relate his work to small group sociology (Hare, Borgatta, & Bales, 1955). While Greeno acknowledged that this is "basically correct" (p. 43, see also endnote 4, pp. 67–68), he was concerned that these terms implied that "task" functions are not social, i.e., not *group* functions.

In fact, small group sociology usually treats both "task" and "social" functions as collective functions. Nevertheless, I suspect that his reservations may indicate that the task/social distinction neglects something important to his analysis.

Content, Control and Computation

To further clarify the meaning of the functions that Greeno is attempting to synthesize it may help to go back to the basic model that he says he is "appropriating." His basic model seems to be the computational model of problem-solving used in cognitive psychology and classical AI, which he then applies to group problem-solving. If this is correct, then it may be helpful to consider the functions that are interrelated in the traditional computational model of problem-solving.

The most general functions in computational models of problem solving are content and control (Newell & Simon, 1972; Rich, 1983). As a popular expression in computer science puts it, "Computation equals knowledge plus control." Knowledge content is represented by symbolic patterns, typically lists of symbols nested inside of other lists, like "(on((table) (pyramid(blue))))". Such lists are used to describe both facts and transformational rules or operations in the domain, such as the current state of a chess-board and the possible valid moves of the pieces. Control is represented by a computer interpreter that reads these lists in a certain order, such as top to bottom, left to right. Such an interpreter searches for a pattern on a list, such as the "if" part of an "if-then" rule, which, having been found, sends it off to search for the "then" part in other lists that have this same pattern in their "if" half. Solving a problem consists of finding a sequence of symbolic "if-then" transformations that eliminates the difference between a symbol structure describing an initial situation and one describing a goal situation. When the difference is eliminated the problem is "solved," the sequence of computer operations used representing a plan, or sequence of actions to be taken in the external world to achieve a similar change in it's the states the plan describes.

I believe this is the basic model that Greeno uses while transferring it to group problem-solving. The "information structures" that group members manipulate are external, publicly available problem-representations, like diagrams on a chalkboard.[4] Group members manipulate these representations, seeking to solve or resolve a problem. Control of the process is determined by the "participation structure," or set of norms governing who can legitimately insert a suggestion at a given point. As a result, the group is viewed as functioning as a kind of computational system, modifying problem-representations by allowing (or empowering) different individuals to contribute changes to them at different times.

If this is the model that Greeno is drawing upon, then the two functions being interrelated appear to be the *content* and *control* aspects of group problem-solving. Content refers to changing public problem-representations, while control refers to the "positioning" of interactants relative to one another or to differing content areas. Greeno calls these functions "informational" and "interpersonal," which may be adequate but "content" and "control" or "knowledge" and "control" might indicate a bit more clearly that his primary concern on the social-interactional side is the regulation of the problem-solving process.

To apply the computational model just outlined to *group* problem-solving various adjustments have to be made to the "standard" model of cognition. Since group members have to agree on suitable representations, Greeno introduces the concepts of "problematizing" and "reconciling," which refer to coming to *public* agreement on a suitable representation of the problem or its solution. Once the group agrees publicly that a proposed representation is acceptable, it becomes the ground for further discussion and modification.[5] In other words, it functions as "knowledge." The control side is analyzed by considering the way people are "positioned," or given authority relative to other individuals or knowledge domains. A teacher may "position" a group of students by delegating them the right to define their own problems and solutions, for example, or a student may be "positioned" by peers and themselves to a certain status within the group.

In such a system, each problem-solving step depends on its being publicly acceptable to the group (it is possible that no one privately concurs). In routine problem-solving a representational change presumably either meets or fails to meet public goal-constraints and does not invoke much discussion. The more interesting case occurs when there is conflict over standards or their interpretation. Here Greeno proposes a hypothesis I believe can be roughly stated as follows: *In collective problem-solving groups participants with higher status or authority face lower burdens of proof for proposal acceptance than participants with lower status or authority.* Those of higher status can generally get their assertions accepted with weaker arguments, while those of lower status need stronger arguments.

Greeno uses this principle, explicitly or implicitly, to explain the outcome in each case he discusses. In the first case, for example, two groups of students were unable to reach agreement about whether an orca is a dolphin or a whale, apparently because both were equally "positioned" and neither had a powerful enough argument to convince the other. In the first guppy discussion, a higher status student, "M," was willing to concede a point about reproductive rates to a lower status student, "L," when "L" presented a particularly compelling argument. "L" was able to get agreement despite having lower status because her argument was strong enough to overcome the burden of proof caused by her status disadvantage. In the second guppy example, the higher status student, "M," was able to gain agreement on an incorrect suggestion despite resistance from "L" because L's counter-argument did not to meet the higher burden of proof needed to override M's status advantage.[6] In the first Wisconsin Fast Plants® case (Excerpts 3 and 5 in Appendix B), one teacher, RL, supported Anneke's way of representing the distribution of plant heights which facilitated the group's arriving at a correct decision despite the fact that Jewel remained unconvinced. Having lower status than the teacher and no counter-argument strong enough to sway the group, Jewel could not get her idea accepted. In the last example (Excerpt 9), another teacher, MR, validated certain student responses and manipulated student representations in order to draw out the answers he wanted. He was able to push answers through to public acceptance even if it involved putting words in the mouths of the students who might have disagreed because of his higher status. In each case the explanation for the adoption of a particular representation involves an interaction of argumentative strength and social strength, illocutionary force and social force. When someone has a better argument, less authority is needed. When they have a weaker argument more authority is needed.

Uses and Limitations

Greeno's approach should by now be clear. He borrows the computational model from cognitive psychology and applies it fairly directly to small group problem-solving. When applied to small groups, this approach depicts problem-solving as a sequence of publicly agreed upon operations that change public representations of a problem and/or solution from one form to another until the difficulty is resolved. Control of this process is determined by norms specifying who can legitimately speak or assert themselves in relation to other people or contents ("positioning"). In the case of competing proposals, acceptance involves an interaction of argumentative "force" and positional authority.

If this adequately summarizes Greeno's approach we are finally in a position to consider its uses and limitations. It is easiest to begin by noting what the approach excludes. I have characterized it as focusing on the small group level even though Greeno characterized his focus as "activity systems." There is an important reason for his emphasis on activity systems, which is that he does not want to fall back into traditional entitative thinking. He does not want to replicate the traditional way of thinking that views an individual as an entity that has thinking inside of it at the level of the group, as though the group were an entity with thinking inside of it. As a result he is careful to depict the "activity system" that solves problems as including blackboards, chalk, computers, VCRs, teachers, and so forth, and not just the "group." On the other hand stating that his focus is on an "activity system" rather than small group problem-solving tends to hide the fact that his focus is pretty exclusively on the group level of analysis. As he points out, he is *not* focusing on individual cognition or learning (p. 44). As a result the analysis does not tell us what any given individual thinks or learns. Note that this does not mean that I am considering thinking or learning as located inside of the individual independent of the environment that makes it possible, but individuals can learn and this differs from group learning or problem-solving. It is also clear that Greeno is not focusing on problem-solving or learning at the organizational, communal or national levels, some of which have been considered in other applications of the computational model (March & Simon, 1958; Cyert & March, 1963; Allison, 1971). Nor is Greeno doing a multi-level analysis, such as trying to solve the micro–macro problem by linking individual and group cognition (Knorr-Cetina & Cicourel, 1981). These comments are meant only to clarify what Greeno is doing by way of contrast with what he is not.

If Greeno is focusing exclusively on the small group level, then what does his work adds to the social psychology or sociology of small groups. Traditional studies of leadership in small groups studied how "task" and "social" functions become differentiated and allocated to different leaders (Hare et al., 1955). They also studied conditions leading to these functions being separated or united under a single leader (Verba, 1961). This literature tended to be process-oriented and neglected the content of group-problem solving. Greeno adds to this work by giving much more attention to problem-solving content, as in the public problem-representations used by group members. His work also relates to other sociological research that has studied how the social status of group members affects their ability to influence group problem-solving (Berger, Conner, & Fisek, 1974; Cohen, 1994; Cohen & Lotan, 1997). This work typically finds that members with higher status have more influence on problem-solving even when there are no differences in expertise between members. There are more interesting findings as well, but Greeno's research adds something important by bringing into the analysis concern for the strength of the reasons offered for a conclusion, suggesting that illocutionary force and social status interact in group judgments. In both instances concern for content is added to analyses that have traditionally focused only on interactional process.

Bringing both content and control within one analysis may have important implications for instructional design. The sociological literature has been concerned primarily with creating more equal status groups and reducing the extent of external authority, such as by organizing classrooms with multiple tasks rather than a single task, or designing tasks that provide their own feedback about success rather than relying on feedback from an authority. Much less attention has been paid to the significance of different forms of representation or ways of ensuring that reasoning is publicly observable. The normative side of Greeno's work seems to involve figuring out how to create conditions that give reasons more "power" while making social status less important in group deliberations.

A more difficult question is whether Greeno's analysis truly manages to combine the strengths of cognitive psychology and sociolinguistics as intended. Since Greeno borrows most fully from cognitive psychology it should come as no surprise that the strength of this field are most fully represented in his work. Even though some of the strengths of the computational model have not been retained, since we have no way of knowing how the participants' suggestions are generated, many have been, such as a focus on step-by-step changes in representations. Sociolinguistic or social-interactional concepts and concerns, on the other hand, are not nearly as fully incorporated. The term "positioning" suggests that a process is involved and not just an outcome. People negotiate their roles, statuses, or identities with one another using norms as a cognitive and political resource, rather than simply being positioned in a fixed way. There is also a history of "positioning," involving the development of relationships over time. These processes tend to be reduced or ignored in Greeno's analysis making it apparent that a focus on cognition has led to inattention to the socio-emotional dramas involved in status and identity struggles (Strauss, 1959). Greeno's approach remains a cognitive theory at heart, like the cognitive psychology from which it draws.

Even if it is not the "Holy Grail" synthesizing cognitive psychology and sociolinguistics that Greeno originally sought his approach still makes an interesting contribution. The notion that reasons and power interact in determining acceptance of an idea is simple yet avoids both an over-intellectualized emphasis on reasons alone, and an overly politicized emphasis on power alone. It is an interesting hypothesis that deserves further study. What remains to be done to achieve a fuller synthesis is to take the socio-emotional side of group interaction as fully into account as the "informational" side.

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Notes

1. "Artificial" distinctions composed by human artifice are, of course, also "natural" in the broad sense, but not in the sense that a specific distinction is universal to the species.
2. Hutchins (1995) explored this idea in a study of the way a ship crew solved the problem of navigating a harbor.
3. I remain a bit confused by the examples of differing levels of temporal organization in the columns of Table 3.1. One interpretation is that they contrast activities of differing temporal duration in which one engages, such as tying one's shoes versus completing college. An alternative interpretation is that they involve differing levels of change (analogous to distance, velocity and acceleration in physics). The latter hierarchy would go from routinized behavior, to change in behavior due to receipt of new information, to change in the change new information makes (learning a new habit), to change in the way the change in the function of the new information occurs (learning to learn), Bateson (1972).
4. Verbal utterances presumably also function as publicly available "information structures" in Greeno's analysis.
5. Later in the paper Greeno switches to "resolving" instead of "reconciling." I suspect he finds the former concept attractive because an acceptable solution may involve reconcepualization of the problem and not merely compromise between proposed solutions, but the exact distinction remains unclear.
6. As Greeno puts it, "We explain the difference [between these two guppy cases] in terms of a threshold for problematizing an issue, which is partially determined by the positioning of students.... We hypothesize that the threshold was exceeded in one case and not the other because of a difference in the strength of information that was presented..." (p. 51).

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Chapter 7
Working Both Sides

Kay McClain

Introduction

In his paper, Greeno outlines his and others' work toward a theory of cognition and learning in interaction. He states

> [t]he ideal result of this would be a theory that explains *dynamic aspects of interpersonal interaction* with the same degree of rigor and specificity that are achieved by sociolinguistics accounts, and explain the informational contents of interactions with the same degree of rigor and specificity of information-processing accounts. (p. 41, emphasis added)

This is a noble undertaking and one that has positive ramifications for numerous aspects of educational research. The generation of theory implies significant work over time with the outcome having predictable power in a variety of settings. In order to improve the quality of educational research, we need such theories. Ed Silver expressed this sentiment in his March 2003 editorial in the *Journal for Research in Education* where he noted, "[t]here is little disagreement within the profession that the quality of education research needs to be improved."

Accepting the importance of Greeno's work, not just here but throughout his career, I offer my commentary from the position of a researcher who first worked "from the inside out" and who now works "from the outside in." My *identity* is that of a mathematics educator with a theoretical commitment to design research (cf. Brown, 1992; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; McClain, 2002a). To clarify, for almost 7 years I collaborated with Paul Cobb, Koeno Gravemeijer and others[1] in the execution of classroom design experiments in which I acted as the teacher.[2] In these settings, I was working from the inside out to first, *in action,* make sense of students' understandings so that I could planfully orchestrate classroom discussions. Later, I would conduct retrospective analyses of my interactions by analyzing from the "outside" what I had previously participated in on the "inside" (cf. Cobb & McClain, 2001; McClain, 2002b; McClain & Cobb, 1998). In these

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instances, I worked to understand both the students' and my learning through normative patterns of engagement. The theoretical lens that I adopted for most of my analyses of the classroom is that of a social constructivist with a strong emphasis on tools. However, the Emergent Perspective Framework (cf. Cobb & Yackel, 1996) provided normative constructs for my analyses. Reading Greeno's account of his proposed theory, I find his levels of accounts of cognition in interaction strengthen my previous orientation by more clearly articulating levels of a progression of conceptual understanding. However, I am left wondering what the means of support are for shifts between the levels. As an example, if one knows that a student is a motor counter (cf. Steffe & Cobb, 1988), how does that inform task selection and instructional decision making on the part of the teacher in order to support the students' ability to count in more sophisticated ways. In a like manner, what means of support are needed to support students' ability to shift from the routine comprehensions in *Level One* of his analysis of cognition in activity to the more sophisticated emergent understandings in *Level Two*. Clearly, having a way to analyze the students' current abilities or ways of reasoning is crucial. However, I view it as necessary but insufficient for supporting learning. It is this stance that I take in my commentary.

In the following sections of this paper, I relate Greeno's theory and his three analyses of classroom episodes to my work as a mathematics education researcher focused on the proactive role of the teacher. I begin with my analyses of episodes from the Wisconsin Fast Plants® classroom and then move to my current work with teachers. I provide instances from each setting that both highlight the strength of Greeno's theory while calling for an explication of the role of the teacher, appropriate tasks and other means of support in initiating shifts in students' and teachers' learning.

Comprehensive Theories of Student Learning

Although Greeno's framework is well grounded and offers the field a way to account for learning which attends to both the cognitive and the social, the area of explanation that is missing for me is that of the role of the teacher, tasks and other mediating tools in supporting students' deeper conceptual understandings as they achieve higher levels of cognition (Kaput, 1994, Meira, 1995, 1998; McClain, 2002b; van Oers, 1996, 2000). In the later sections of his paper, Greeno uses two examples from his work to call into question the role of RL and Mark (the classroom teacher) in the episode from the Fast Plants classroom (see Excerpt 5 and Excerpt 9 in Appendix B). In doing so, he implies that both RL and the classroom teacher assumed too much agency, preventing students from achieving more powerful levels of conceptual growth (elsewhere my colleagues and I have defined agency as having authority over both the mathematics that is taught and the sequencing and presentation of that content. See McClain, Zhao, Visnovska, and Bowen [2009]). However, Greeno does not address the role of the teacher in students' development in the two classrooms from his work, only that of the tasks (see reference to Stein et al.). One could argue that he is placing too much agency with the tasks. It was only as I read his analysis of the Fast Plants classroom that I realized his framework does not address the role of the teacher or that of tasks. More generally, it does not address means of supporting shifts in students' levels of cognition. His *interactions* are described as student to student. As a researcher whose career has focused on the proactive role of the teacher, I read his explication of the levels of his analysis of cognition in activity as though they implied a proactive role on the part of the teacher. I, in fact, could envision shifts in that role as the students achieved higher levels of conceptual growth. My interests clearly oriented my interpretation.

I agree with Greeno that the episode involving Mark trying to problematize the lack of scaling was painful to read (see Excerpt 9, Day 28). Scaling is important for students to understand if they are to be able to create generalizable models of data. I have, however, often been in the same situation where the optimal question was beyond my reach. At these times I engaged the students in a game of *guess what I want you to say*, clearly delimiting the learning opportunities for the students. This points to the complexity of teaching that others and I have articulated numerous times (cf. Ball, 1993; Lampert, 1990; McClain, 2002b). Lampert (2001) makes a nice analogy between teaching and steering an unwieldy ship on turbulent waters. I refer to teaching as herding cats. Clearly, Mark's and the students' time would have been better served had he just told them what he wanted them to notice and then tried to find counter examples or non-examples of his proposition. Or, as Greeno suggested, engage the students in a lengthy discussion of this significant concept. However, this instance of Mark laboring over how to proceed does not negate the power of the role of the teacher in the day-to-day learning of students. Nor does it imply that agency should or should not lie with the teacher. Determining the location of agency is the wrong question. Agency should not be located with any member of a learning community, but should *dance* (cf. Pickering, 1995) between students and also between the students and the teacher. These interactions are important in supporting shifts in students' learning.

As an example, in my design work with Cobb and Gravemeijer, we each had a primary interest in the classroom. Cobb's was that of students' understandings, Gravemeijer's was that of the power of a sequence of well-designed tasks, and mine was that of my role as the teacher. Through years of collaboration, I came to understand that true conceptual learning most often occurs at the intersection of these three aspects of the classroom as shown in Fig. 7.1 below.

The intersection of the three regions would therefore define a learning space much like that characterized by Brown (1992) where researchers "engineer innovative educational environments and simultaneously conduct experimental studies of those innovations" (p. 141). This involves iterative cycles of design and research where conjectures about the learning route of the students and the means of supporting it are continually tested and revised *in the course of ongoing interactions*. This is a highly interventionist activity in which decisions about how to proceed are constantly being analyzed against the current activity of the students on a day-to-day basis.

This process begins with the initial formulation of a conjectured learning trajectory and the necessary means of supporting students' transition along its path.

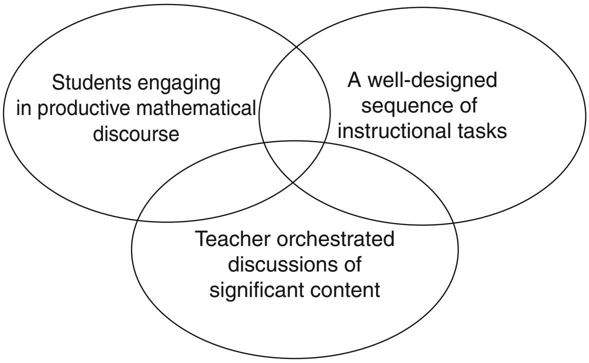

Fig. 7.1 Interplay of students' contributions, well-designed tasks and the proactive role of the teacher

These *means of support* include the choice of tools, tasks and productive mathematical discourse. Although the conjectures are formulated prior to the interaction, the actual learning trajectory is a path that is *laid down while walking* (cf., Varela, Thompson, & Rosch, 1991). It is therefore the learning that emerges in the course of the interaction that actually guides the creation of what Simon (1995) calls the *realized* learning trajectory. This description seems to fit with Greeno's classrooms (e.g. the orcas, mice and guppies). However, the one tool he did not mention was that of the role of the teacher in the selection of tasks and the guiding of discourse. The reader is, therefore, left wondering how the work within the student groups in these classrooms contributed to the learning of other students in the class. Without a carefully orchestrated whole-class discussion, each group becomes an entity unto itself, the interactions are limited to the group, and agency is local. This minimizes the possibilities for learning to occur across the groups. Further, Greeno notes that the informational principles involve ways of achieving coherence of information, including alignment of the situation with the task. But how does this occur? He continues by stating, "[r]easoning processes need to include problematizing inconsistencies by taking them up as discourse topics and resolving the alternative interpretations or opinions that are at issue" (p. 48–49). Again, what is the lever for this action? Does it have to be a student? When is it appropriate for the teacher to initiate the inconsistencies as discourse topics?

If we return to Excerpt 5, Day 26 from the Fast Plants classroom and the interactions involving RL, I argue that his role in those interactions *was* to problematize the students' current ways of reasoning and make them topics of conversation. I do not agree with Greeno that he assumed the authority to decide between the alternatives that were presented. Greeno states that, "RL forcefully posed a rhetorical question, 'How does [the information about the plant numbers] help you answer your question?'" (p. 57). I argue that RL problematized the representation by re-focusing the students on the task at hand – determining the spread of the data and locating the *typical* Fast Plants. Elsewhere Greeno stated that during the Orca controversy (e.g. whether or not Orcas are whales), the "teacher explicitly directed the group to resolve the issue, affirming that they had the authority to arrive at a conclusion and were accountable for doing that" (p. 50). However, the initial controversy arose because of what a staff member at the aquarium told the students; not because of an issue raised by another student. Here we have evidence of the teacher "explicitly directing" students to reconcile an issue in a situation where an outsider introduced the controversy. This fits with Greeno's articulation of the importance of juxtaposing inconsistencies as discourse topics and, through these interactions, reconciling alternative interpretations or understandings. What is missing is accounting for not only student to student interactions, but also interactions that are student to teacher or student to another (e.g. aquarium staff).

In a similar manner, RL's questions problematized the students' representation. In each episode (e.g. Orcas and Fast Plants), we have evidence of practices that encourage reconciling while positioning students in disciplinary discourse with competence, authority, and accountability (see *Level Three* of his analysis of cognition in activity of the table). However, it is the role of authority or the placement of agency that can be debated. I take the position that if the question results in students' ability to problematize in the manner that Greeno describes as *generative reasoning*, the source of the question is not an issue. If the students recognize the problem and develop alternatives, they are positioned with authority and accountability. This is evidenced by the problematizing that occurred for the group of students in their interactions with RL and with the class of students in their interactions with the aquarium staff.

In his chapter, Greeno states,

> Semantically, we have adopted the assumption that successful reasoning corresponds to achieving a coherent network of information, which includes alignment of meanings and propositions that refer to states of affairs in the situation and to concepts and principles in conceptual domains that the participants have access to. We hypothesize that processes that contribute to successful reasoning include detecting inconsistencies in the current information structure, often involving propositions that are asserted that are contrary to propositions that are implied by principles of a relevant conceptual domain. Reasoning processes need to include problematizing inconsistencies by taking them up as discourse topics, and reconciling the alternative interpretations or opinions that are at issue. (pp. 48–49)

I argue that it is the acceptance of the proposition as a *problem* and following up to reconcile the problem that leads to conceptual growth, cognitive development and changes in discourse practice and that this is *not* dependent upon the source of the proposition. The possible sources extend well beyond the students in a classroom.

If we return to the episode of Mark trying to problematize the issue of scaling (Excerpt 9, Day 28), one could argue that since it was the teacher that initiated the problem, the students did not take ownership. However, an alternative explanation could be that, at that point, it was *not a problem* for the students. In other words, the question *they* were answering about the Fast Plants data was not confounded, for them, by a lack of scale. I would conjecture that at this point, spread was synonymous with range and they were not attending to how the data were distributed.

Not wanting to leave Mark struggling to manage the discussion of scale (see Excerpt 9, Day 28), I move on to an episode in which he interacts with students about one of the graphs of the fast plant data (see Excerpt 10, Day 28). The group of students who are at the front of the room did not create the graph they are trying to explain (see Fig. 2.6). It appears that Mark has students explain others' graphs in an attempt to get them to de-center from their own approach and take seriously the work of others. At first, Ian finds the graph "a little confusing." Mark attempts to mediate by asking if Ian would like to re-orient the graph by rotating it 90°. I assume that at this point Mark is trying to provide an alternative visual by presenting the graph as similar to a horizontal bar graph.

However, Ian states, "Well, I'm not sure." Mark does not press. When Ian comments that it is "neat how they did it," Mark asks Ian to explain what it is about the graph that helps the group "see that the numbers are spread" and "what a typical fast plant would be?"

Kerri responds and explains the spread by referencing the graph.

Excerpt 10 [0:20:22–0:20:45]

```
0:20:22 Kerri:       = Well to see how they're spread you have to
                     look up at the highest one (0.5) and then if
                     they're (0.7) so then like on the highest line
                     (0.8) that would be like (in) the highest
                     (1.0) like the (0.4) highest one and the
                     lowest (0.5) would be down here (0.4) and if
                     there's one along the same line then you just
                     look to see how far out this way it is
```

Mark then asks the group if they can circle the location on the graph where the typical fast plant would be. A lively discussion ensues during which Kerri and Ian each determines the location of the typical fast plant. However, from the transcript it appears that Kerri and Ian have different interpretations.

Excerpt 10 [0:21:06–0:21:06]

```
0:21:06 Kerri:                ⌊It would be ⌊(over here)
0:21:06 Student1:    = Use the key! =
```

At this point another student in the class calls attention to the key on the graph for interpreting the symbols and she is encouraging Kerri to use the key to interpret the graph correctly.

Excerpt 10 [0:21:07–0:22:03]

```
0:21:07 Student2:    = There's a key it's at the top
0:21:09 Kerri:       Look at the key.
0:21:10 Ian:         That means there's three der or four der
```

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0:21:13 Kerri:      There's (.) four of that number ⌈so
0:21:15 Ian:                                        ⌊There's
                    actually fi:⌈ve.
0:21:16 Kerri:                  ⌊And (0.7) I know.
0:21:18 Ian:        Hehh
0:21:19 Kerri:      And X (.) means one of them, star (0.9) means
                    there's two::, (0.4) that one (0.9) this with
                    the box around it? is three and that is four
                    (1.2) so:: you look to see like (.) (if) the
                    different symbols? (1.1) and that's one (0.9)
                    that's the biggest number=
0:21:44 Ian:        =I think to find the um a typical one you'd
                    look like toward the middle of the graph? and
                    find a point that was closest to the middle?
                    (0.7) because then up and down you'd find the
                    middle and side to side you'd find the middle=
0:21:57 teacher:    =So would you say that yer >I think you said<
                    the typical was probably this one or would it
                    ⌈would you use
0:22:01 Ian:        ⌊Somewhere around there.
0:22:03 teacher:    Okay.
```

From this exchange we can infer that Kerri had a *modal* interpretation of typical and Ian was trying to locate the *median*. Kerri used the key to identify the symbol that indicated the highest frequency and called that "typical." However, Ian wanted "typical" to be the middle of the data going either up and down or side to side. Both of these are valid ways of characterizing typical and, throughout the conversation, Mark does not try to position one over the other. He simply mediates Kerri and Ian's conversation. Although we do not have data beyond this point, Mark has created a situation in which to juxtapose the two different methods in the course of classroom interactions. This can create an opportunity for the students to problematize and reconcile the differences while positioning the students in disciplinary discourse (*Level Three* of his analysis of cognition in activity). This is a powerful move on the part of the teacher because he is able to build off of the students' current interpretations to problematize the issue instead of trying to introduce it himself as with the concept of scale. This episode can be contrasted with the earlier discussion of scaling where one could argue that no learning occurred. Here we see evidence of the students presenting two alternatives for "typical." Since this is not a mathematical term, the ideas proposed are both logical with respect to the students' interpretations of typical. This conversation can therefore serve as a didactic object (cf. Thompson, 2002) in later conversations during which students can reflect on this prior activity.

The following section addresses my current work with teachers. My prior work in design classrooms provided a conjectured learning trajectory for supporting teachers' professional growth. This has been constantly modified and revised in the course of a 7-year collaboration. Here, I clarify how Greeno's proposed theory can offer an additional lens for making sense of teacher learning and build toward a comprehensive theory of teacher learning.

Theories of How Teachers Learn

My recent work involved collaboration with a community of middle-grades mathematics teachers. In our 7th year of work, we achieved the point in our collaboration where we co-designed our work and took mutual responsibility for the agenda. This was achieved only through a process of long-term negotiation. We initially began with the goal of improving the teachers' understandings of statistical data analysis. From there we moved to students' understandings, the role of worthwhile tasks, and the role of the teacher in orchestrating these interactions. The teachers have designed instructional units along with CD-based resources from their classrooms. As the "instructional leader" for the group, I was initially perceived as having agency for the mathematics. Over the course of the 7 years, the agency shifted much like Pickering (1995) described in the dance of agency.

Again, in these settings, I first worked from the "inside out" to try to make sense of the teachers' understandings and have also conducted retrospective analysis viewing the data from the "outside in" (cf. McClain, 2002b). In my analyses of the teachers' learning, I can draw strong parallels to my earlier work, the teachers' development and Greeno's levels of accounts of cognition in interaction. In many instances, his levels help illuminate issues I was previously unable to explain.

However, part of my difficulty in conducting analyses of the teachers' learning lies in the lack of current theories to explain *how teachers learn*. Ball and Cohen (1999) call attention to the lack of a theoretical basis for teacher development when they note that what is missing in the field "are carefully constructed and empirically validated theories of teacher learning" (p. 4). They continue by stating, "theories of professional learning have been implicit and undeveloped" (p. 5). Simon (1997) concurs by arguing that successful efforts necessitate "the generation of a research base on the development of teachers" (p. 55). Thus, the limitations of the current research call attention to the need for theoretical work that can provide a basis for understanding how to account for teacher learning. What typically occurs is that we borrow a theory of how students learn and fail to account for what teachers "bring to the table" or we work in that area between anecdote and analyses which lacks the rigor the field needs to build theory. It is here, in the field of teacher development, that I believe Greeno's work can have the most impact. In the following paragraphs, I will situate my claim in my ongoing work with teachers.

The starting points for the teacher collaboration entailed the teachers first engaging in a sequence of statistical data analysis tasks as learners. They then used their own experiences at first analyzing and subsequently critiquing the results of their analysis as a basis for engaging their students in the same tasks. The iterative process of task solving and task posing provided the means of supporting the teachers' developing understandings of statistical data analysis while placing the students' ways of reasoning in the foreground. This also provided intellectual resources for the teachers to use as they orchestrated whole-class discussions. In this process, students introduced non-conventional ways of graphing data that attended to the question to be answered much like in the Fast Plants episode. As a result, the teachers were pushed to understand these graphs in the context of the analysis as statistical data analysis ideas were highlighted in the course of ongoing investigations. The teachers were able to discuss the results of their own analyses and then later, the results of their students. This activity supported our broader goal of investigating what should comprise the middle-grades units on statistical data analysis by first coming to understand the mathematics ourselves.

An important aspect of this process was ensuring that the tasks also created genuine problem-solving situations for the teachers. This provided opportunities for the teachers to reconstruct the mathematical justifications for the tasks in the course of their own experience. The second phase of planned activity involved their anticipating their students' responses to the tasks and then testing those conjectures in the classroom by having their students engage in the same tasks. This was followed by informal analyses of their students' ways of reasoning and subsequent whole-group discussions among the teacher community of their analyses. The process involved a proactive role on my part of initiating and guiding discussions around significant issues of mathematics and pedagogy. The iterative process of task solving and task posing was designed to provide the means of supporting the teachers' developing understandings of the mathematics that underlies statistical data analysis. This supported a generative cycle of activity during which teachers' learning was enhanced by their own and their students' activity (cf., Franke, Carpenter, Levi, & Fennema, 1998; Franke & Kazemi, 2001). In this process, teachers' classrooms therefore became sites for their own and their students' learning.

One of the tasks posed to the teachers during our 2nd year of collaboration involved analyzing data on the temperatures inside football helmets that contained a liner for reducing heat.[3] I began by asking the teachers if any of them were involved in coaching or officiating students' football games and if so, what precautions they took against heat exhaustion. The teachers engaged in a lengthy discussion of state and district mandates concerning required breaks and water consumption. An aspect of this included the players having to remove their helmets during breaks since the helmets were seen to hold heat and increase the possibility of heat exhaustion. Teachers spoke of the death of players at practice where such measures were not observed and the importance of knowing the signs of heat exhaustion in places such as Phoenix. I then asked if any of the teams used helmets with heat protector liner inserts. This was new information, but the idea was very appealing. Next, I asked how one might go about determining if such a device were effective. In the subsequent discussion, the teachers delineated design specifications for testing such a device including a control group under similar conditions. It was during these discussions that the teachers came to understand the importance of sampling techniques and the relation to sampling to generalizations or inferences that could be made from the data.

Following this data creation discussion, I presented two data sets to the teachers. The first set was data on the temperatures taken from inside standard helmets worn by sixty players after 2 h of practice. The second was of the temperatures taken from inside helmets of sixty players under the same conditions, but with heat liners (see

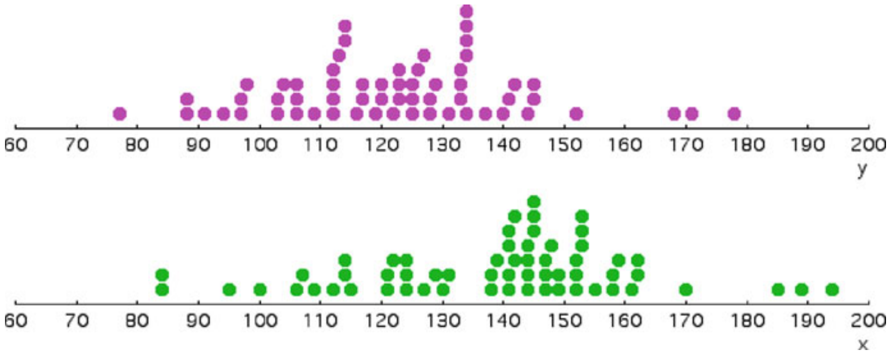

Fig. 7.2 Football helmet data displayed in the computer tool

Fig. 7.2). These displays were screen captures of the data as inscribed in a computer-based tool for analysis.[4] The task was to determine if the liners were effective in reducing heat inside the helmet.

Teachers first engaged in what they had come to call *informal analysis of the data*. This involved looking at the data globally to determine initial conjectures about trends and patterns. This would be followed by a *formal analysis* using the computer tool in which they used the features of the tool to clarify and verify the patterns and trends they described in their informal analysis. This process had proven to be very powerful when working with students in that it helped the students focus their activity with the computer tool instead of randomly selecting features and resulting data displays.

As the teachers worked informally, they created cut points in the data at certain degrees by drawing a vertical line through both data sets. They also identified the clusters in each data set by circling the data values or partitioning them in some way. As they talked, they reasoned that the distribution of the data on the temperatures in the helmets with liners were "generally in a lower range." Their initial conjecture was that the helmets liners were effective in reducing heat inside the helmet.

After several minutes of working informally, the teachers moved into the computer lab and accessed the data on the computer tool. As the teachers worked, they used different ways of organizing and structuring the data to tease out the differences in the two distributions of data in order to justify their conjecture. In the process, they were able to characterize the trends and patterns in the data both within and across the data sets.

As the teachers shared the results of their analysis, an issue that emerged as significant was that of reasoning multiplicatively about the data. As an example, Pauline and Diane structured the data using the four-equal-groups inscription as shown in Fig. 7.3 and reasoned about the proportion or percentage of data that fell in certain ranges. In particular, they argued that, "75% of the temperatures in helmets without liners is greater than 50% of the temperatures in the helmets with liners." This, they argued, was justification for using the liners. This was a significant point for the teachers as they realized that a similar argument could be made by creating a

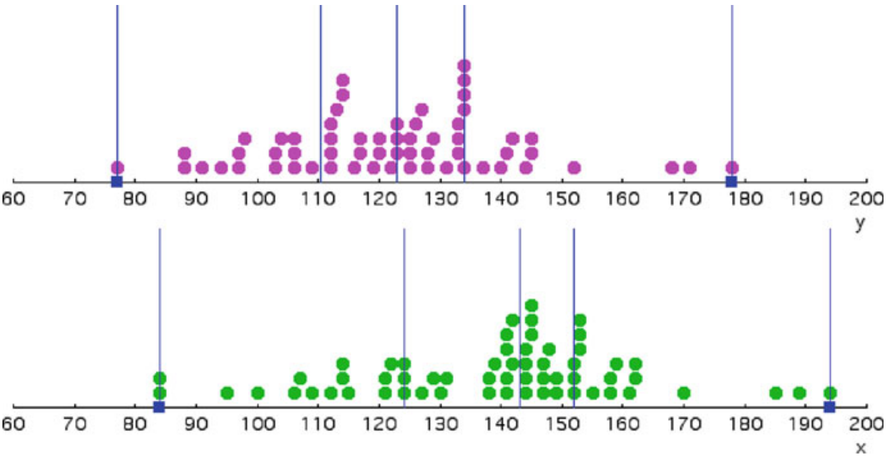

Fig. 7.3 Helmet data partitioned into four equal groups

cut point at, say, 123° by using the create-your-own-groups option and then finding the number or percentage of data values that fell above or below the cut point (see Fig. 7.4).

This would be similar to the argument made from the four-equal-groups inscription since nearly 50% (or 29) of the temperatures from the helmets with liners were below the cut point of 123° and nearly 75% (or 46) of the temperatures from the helmets without liners were above the cut point.

Other arguments included Carey and her partner noting that when using the two-equal-groups structuring, both the median and the upper extreme of the temperatures in the helmets without liners were "much higher." However, in comparing

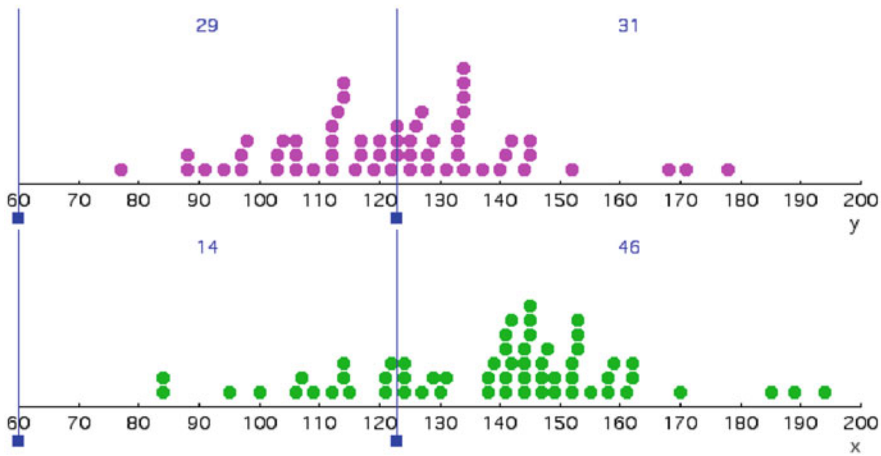

Fig. 7.4 Helmet data partitioned at 123° F

their analysis to that of Pauline and Diane, they reasoned that the four-equal-groups inscription provided more "information about how the data were really distributed across the axis."

My role in this interaction was limited. I did begin the discussion by choosing the first group to present. That was purposeful. However, after the first presentation, the teachers offered alternative representations[5] that they felt justified a stronger argument. At this point, they were able to make that distinction. Comparing and contrasting solutions was a powerful part of the interactions. As a result, I would argue that the teachers were communally operating at Greeno's Level 4 of his analysis of cognition in activity (see Table 3.1). This is evidenced by Greeno's characterization of Level Four as

- sustained, persistent participation in the learning practices,
- commitment to learning goals,
- general motivational traits,
- legitimate peripheral participation, and
- productive agency in relation to the community's joint enterprise of learning.

Although my role in this exchange was limited, I would argue that at this point I was a legitimate member of the community and we shared agency for the mathematics. In addition, the interactions had elevated such that the teachers were able to make meta-level comments about the variety of analyses by looking across the representations.

In retrospect, it would have been helpful for me to have Greeno's framework to use in my collaborations. It would have provided a means of characterizing the changes in the teachers' learning and their ways of participating within the community. Because of the lack of theories or frameworks to explain the process of teachers' learning, I was only able to reason about how to proceed by conducting ongoing analyses of their understandings of statistical data analysis. I had a conjectured learning trajectory for this aspect of the collaboration. However, what makes the work with teachers so complex is that the learning of the mathematics is intertwined with their deepening understandings of pedagogy and understandings of students' diverse ways of reasoning. It is here that Greeno's framework would have provided a lens for accounting for shifts in the interactions around such issues.

Conclusion

I want to end by returning to my initial claims that Greeno's proposed theory is well grounded and offers the field a way to account for learning that attends to both the cognitive and the social. However, his lack of attention to the role of the teacher, tasks and other mediating tools in supporting students' deeper conceptual understandings is troubling. In light of this, I do believe that Greeno and colleagues have made an important contribution to the field with the proposed theory. My understanding is that its value lies in making sense of students' current understandings. As I noted, it takes account of the cognitive while situating learning in the social context of interactions. This is necessary for those of us whose work lies in the complex setting of schooling. However, what is yet to be explained is *how do teachers and/or researchers support shifts to higher levels either with task sequencing or orchestrated discourse?* The utility of what is proposed here will have a broader impact when the community can build from this contribution to develop a *framework for action* (cf. diSessa & Cobb, 2004) that takes Greeno's theory as a basis for conjectures about how to support shifts between the described levels of his analysis of cognition in activity. diSessa and Cobb make a distinction between Grand Theories and Frameworks for Action. "[T]he theory or theories behind frameworks for action are relatively inexplicit, complex and often involve multiple and very diverse elements that cannot plausibly be brought under a single umbrella" (p. 82). I would argue that this is the case for understanding teacher change. How do we coordinate their learning of mathematics with knowledge of pedagogy and knowledge of how to use students' diverse ways of reasoning as intellectual tools in planning for instruction? A first step is to develop theories or frameworks that account for individual aspects of learning and then integrate these multiple frameworks into a Grand Theory. At present, the field of teacher education does not have sufficient frameworks for the meta-level work of theory building. However, what Greeno proposes can serve as a contributing framework to this endeavor.

However, it is important to clarify that this process of theory development requires a commitment on the part of the research community. As diSessa and Cobb (2004) clarify:

> Theories have always displayed a principal part of the power of elegance of science. They embody generalization, bringing order to a vast array of seemingly disparate phenomena that come to be seen as special cases of some theory. They encapsulate the most secure of our knowledge claims at any stage of scientific advance. They enable us to discriminate between relations that are necessary and those that are contingent. They delineate classes of phenomena that are worthy of inquiry and specify how to look and what to see in order to understand them. (p. 79)

The formulation of theory, therefore, requires the contribution of numerous players. In order for a proposed theory to emerge, it must have predictive power in a variety of settings. It must have operationalized constructs that "specify how to look and what to see." These constructs need to be able to make distinctions that matter. In order to generate theory in the field, we must be willing to take the proposed tools offered by others and apply them in a variety of settings, staying true to their intended purpose. In this case in particular, if we can take the framework and expand it to account for more than it was originally designed, then we are better positioned to build a theoretical basis for work with teachers. Since there are no current theories that account for teacher learning, we must do more than just co-op theories of student learning. We have to adapt and revise in the course of our work to accommodate the complexities of teaching that need to be understood to ensure that learning occurs. Greeno's work offers us one path for this journey.

Acknowledgements I would like to thank the teachers in the Madison School District who participate in the Vanderbilt Teacher Collaborative at Madison [www.vtcm.org]. The analysis reported in this paper was supported by the National Science Foundation under grant REC-0135062.

Notes

1. Janet Bowers, Erna Yackel, Maggie McGatha, Lynn Hodge and Jose Cortina were each, at some time, members of the research team.
2. Although I had primary responsibility for teaching, members of the research team would often interject questions for clarification.
3. A detailed analysis of this episode can be found in McClain and Schmitt, 2004.
4. Koeno Gravemeijer, Paul Cobb, and Janet Bowers developed the computer-based tools in collaboration with designers at the Freudenthal Institute as part of research conducted by the first author, Paul Cobb, Koeno Gravemeijer, Maggie McGatha, Lynn Hodge, Jose Cortina, and Carla Richards.
5. In using the term *representation*, I do not mean to convey the double sense of the external and internal means for keeping information. I choose this over Latour's (1987) term *inscription* since the language of representation was used with the students and teachers.

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Chapter 8
Responses to the Commentaries

James G. Greeno

I am honored by and grateful for the careful, thoughtful, stimulating commentaries given by Macbeth, Collins, Bredo, and McClain to my position paper. Each of them presents questions and challenges that problematize significant issues in the conceptual territory in which I am trying to contribute toward better understanding.

Response to Macbeth

Doug Macbeth's commentary presents a fundamental challenge to the program that I am trying to contribute to. I was somewhat stunned when I first read "A commentary on incommensurate programs," because his characterization of the relation of individual cognitive and sociocultural programs in my attempt at a merger is just the opposite of the relation I had in mind. I had viewed the merger as a sociocultural takeover of individual cognitive concepts and methods. Doug wrote, "he [that is, I] has recruited the situated perspective to a [cognitive] project that seems largely unchanged by the recruitment" (p. 78), that is, a takeover by cognitive concepts and methods of the program developed by Garfinkel, Sacks, Schegloff, Suchman, Jordan, Lave,[1] and others. Doug's perspective is valid. As he also wrote, "The analytic program – a program of theorizing formal structures, hypothesizing their relations and measuring the conjectures to the aims of general theory – is virtually unchanged. The project is one of assimilation, instead, assimilating the notion of a 'situated perspective' to the very tasks whose critique leveraged the innovation" (p. 78). My effort is to work toward a theory in which analyses have the same general shape as those developed in the individual cognitive program, but focused at the level of activity systems instead of individuals. Doug argues that this would be an appropriation of the situated program by cognitivism, whereas I had thought it would be an appropriation of the cognitive program by situativity. Perhaps who is

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the appropriator and who is the appropriatee is in the eye of the beholder, but I now think I understand that both perspectives make sense. Thank you, Doug.[2]

Doug's commentary makes me realize that I need to understand meta-scientific aspects of the attempt I am making to move toward a more integrated science of learning and cognition. Doug correctly understands that an effort toward explanation is central in the scientific program that I try to pursue, that I characterize explanations as arguments in which hypotheses serve as premises, and I value the precision of inference-making that can be gained by representing hypotheses formally. Doug correctly perceives that I don't think that these meta-scientific commitments change when the analytical focus is shifted from individuals to activity systems. But maintaining that meta-scientific position, in Doug's view, contradicts meta-scientific commitments that are crucial in the situated approach of ethnomethodology. For example, he writes "We understand the promise of explanation well enough in the culture of science. That the situated perspective is being hitched to it may be the deepest innovation that Jim is proposing; explanation is not the kind of work studies of situated action normally do, or can do, in my view" (p. 84). About hypotheses, in his analysis of an episode that he compared with mine of the same, "[Jewel] and April have discovered a counting game that can't go on *that* way. . . . It *does* have to do with a local history of moves on the graph paper, but in an entirely practical, rather than disciplinary way. We don't need hypotheses to account for it – hypotheses won't account for it – but descriptions of what, indeed, they are doing, might" (p. 95). And about formally represented hypotheses, Doug writes, for example, "Rich and the students are not working on an abstract or representational field, but a material one. It is only *as* a material field that his instruction – his methodic questioning, hinting and practical demonstrations that lead to agreement – can work. They are not organizing an abstract formal structure, but a local field of places and reckonings, and are led to the practical activity of 'counting' of a kind" (p. 95).

First, about the field of students' and teacher's activity, I think that my perspective is aligned with Doug's. I want my analyses to represent their "local field of places and reckonings" and to characterize their practical activities. I agree that *they* were "not working on an abstract or representational field", and were "not organizing an abstract formal structure." However, it does not follow from these framing assumptions about activity that as analysts, *our* practical activity cannot benefit from including representational practices in which we construct symbolic structures with which we attempt to represent important properties of the activities that we observe in the settings that we study. A major goal of research is to improve the forms and contents of these representations, bringing their contents into better alignment with phenomena and developing forms that more felicitously support reasoning and understanding. But use of a formal structure of representation in an analysis of activity does not imply (nor should it be thought to suggest) an assertion that the people whose activity is analyzed are "working on an abstract representational field." If they are, it should be understood as a component of their practice, as the representational forms we use are components of ours.

Next, about explanations and hypotheses, following Toulmin (1972), Kitcher (1993), and many others. I hold that improving resources and methods of explanation is the central aim of scientific work, and that hypotheses are what we explain with – that is, the premises of explanatory accounts are hypothetical statements. Somewhat presumptuously, I understand accounts of talk by conversation analysts to be explanatory. It seems likely that my use of the terms "explanation" and "hypothesis" may be broader than the meanings Doug has in mind.

This means that there are meta-scientific issues that need to be addressed toward the aim of achieving the kind of integration of cognitive and interactional accounts to which I hope to contribute. Recent discussions in the philosophy of science (e.g., Bechtel, 2008; Darden, 2006) are developing a theory of explanation that includes analyses that would not be considered as explanations in the previously predominating covering-law model (Hempel & Oppenheim, 1948/1953). I believe this more general characterization of explanation can be interpreted as including the kinds of accounts of conversation that Doug and others (e.g., Schegloff, 2007) give in the tradition of ethnomethodology. If this is accepted, then we might conclude that the kind of situative account that I am working to develop and the kind of account that is standard in the practice of ethnomethodology are of the same epistemic type and, therefore, more commensurate that it seemed to Doug that they are.

Mechanistic Explanations. The idea that is being developed is a kind of scientific explanation that specifies a mechanism. Bechtel (2008), Darden (2006), and others argue that understanding scientific explanations as hypotheses about mechanisms gives more valid accounts of recent practice in cognitive neuroscience, neurobiology, and molecular biology. I hope to extend their argument to include explanations in the domain of this volume, at least regarding explanations of phenomena at the level of activity systems.

A concise identification of explanatory mechanisms was given by Machamer, Darden, and Craver (2006):

> Mechanisms are composed of both *entities* (with their properties) and *activities.* Activities are the producers of change. Entities are the things that engage in activities. Activities usually require that entities have specific types of properties. (p. 15)

A mechanistic explanation, on this view, specifies a mechanism schema, "a truncated abstract description of a mechanism that can be filled with descriptions of known component parts and activities" (p. 28). "When instantiated, mechanism schemata yield mechanistic explanations of the phenomenon that the mechanism produces" (p. 29). Mechanistic explanations are hierarchical.

> The levels in these hierarchies should be thought of as part-whole hierarchies with the additional restriction that lower level entities, properties, and activities are components in mechanisms that produce higher level phenomena. (p. 25)

A mechanistic explanation "bottoms out" at a level of "components that are accepted as relatively fundamental or taken to be unproblematic for the purposes of a given scientific research group, or field. Bottoming out is relative: Different types of entities and activities are where a given field stops when constructing mechanisms" (p. 26). A mechanistic explanation that is incomplete, that is, "an abstraction for which bottom-out entities and activities cannot (yet) be supplied or which contains gaps in its stages" (p. 30) is called a mechanism sketch.

It is interesting to note that specifying mechanisms as a form of explanation was found by Miyake (1986) to be a common form of discourse between American university students when they had the task of explaining how a sewing machine works. A typical pattern of explanation in Miyake's data was to identify a function, such as making a stitch, and explaining how the machine accomplishes that function in terms of components of the machine, the cloth being sewn, and thread (that is, entities), and activities of the entities that have the result of performing the function. Participants' explanations typically had two or three levels, with each component of the explanation identifying a function at one level and specifying a mechanism that accomplished that function with entities and activities at a more detailed level.

While Doug did not specify what he meant by "explanation" and "hypotheses," I conjecture (by way of proposing an explanation of his and my different statements about them) that he and I have different meanings in mind when we use these terms. The meaning of explanation that I have in mind is my understanding of mechanistic explanation, and the meaning of hypotheses I have in mind is specification of entities, properties, and activities that constitute mechanisms that (hypothetically, of course) can produce the kinds of interaction that we analyze. I propose for consideration, by Doug and our colleagues, that this is an idea about explanation that is consistent with the accounts that Doug and others provide in their analyses of sequences of talk. I hope that this is correct. If it is, then we can set aside the question of whether explanation and hypotheses are legitimate concerns in the scientific enterprise of understanding interaction. (We could continue to differ about terminology – whether to call what we produce analytical accounts or hypothesis-based explanations – but it would be useful if we could agree that the accounts we produce in our analytical efforts comprise the same kinds of components.)

Examples: Two Accounts Interpreted as Mechanistic Explanations The examples I consider are the two analytical sketches that Doug and I presented of the episode that I called "A lesson in abstraction." In my understanding, both of our accounts are explanatory, in the broad sense of mechanistic explanation that I am considering. That is, they both comprise hypotheses about entities, properties of the entities, and activities that account for phenomena that are interpreted as products of the interactive system. Our analyses differ in our characterizations of some of the entities and products of the interaction. In Doug's analysis, the interaction developed a disagreement and an agreement. In my analysis, the interaction developed information in its common ground. I believe that the informational (or semiotic) contents that are the focus of my analysis are implicit in Doug's analysis. The interactional (or systemic) aspects that are the focus of Doug's analysis are implicit in my analysis. As Bredo pointed out in an earlier draft of his commentary, "Greeno's account is thus much more sensitive to the concerns of cognitive psychology than to those of Conversation Analysis or other forms of social-interactional analysis." I suggest that both of our analyses provide valid explanatory accounts, and their hypotheses can be combined to provide a more complete explanation than either of them provides by itself.

In this discussion, I try to characterize both my allegedly explanatory account and Doug's account, which he calls descriptive, as examples of mechanistic explanation – that is, as systems of entities and their properties, and activities that produced the products that we attributed to them in our respective analyses.

In both of our analyses, of course, entities include the students and teacher who interacted in the episode. Properties of the students and teacher include their positioning in the interaction in relation to each other, in which students were entitled to assert and discuss their, and each others', opinions and the teacher, RL, was positioned with authority to lead in the discussion and to determine when a topic had received sufficient discussion. Material entities include the graph paper with the inscriptions the students had written on it and the data sheet that the teacher had posted. In my understanding, our analyses differ in other entities that are also (I would say) hypothesized. In my analysis, I hypothesize a common ground of information[3] that includes interpretations – that is, meanings – of inscriptions made by the students and the teacher, RL, who interacted with them in this episode.[4] This common ground, I also hypothesize, also included prescriptive propositions about what the representation that they are constructing should or should not include. Doug's analysis, by design, omits what I include in the informational common ground, but includes entities that differentiate states of positioning of the participants more specifically and dynamically than my analysis does.

My analysis focuses on states of affairs that the participants came to understand mutually, including (1) that the vertical positions of symbols in the graph referred to individual plants, and (2) that a feature of their representation did not "matter," and therefore should be erased. I also include some systemic/interactional aspects, although these are less detailed in my analysis than they are in Doug's. These include an inference that Anneke was positioned as restating a proposal to omit representations of plant identities, RL was positioned, first, as a recipient of Jewel's explanation of the way that plant identities were represented and then as an authoritative critic of that feature (even though he did not explicitly disapprove it), and Jewel was positioned, first, as the explainer and advocate of the way that plant identities were represented and then as a participant whose contribution was to be removed from the graph.

Doug's analysis, by design, excludes specifications of information structures of the kind I call states of affairs in common ground.[5] Doug explicitly includes more specific aspects of the interaction than I do, Doug notes that "the general organization of the talk is an alternation between teacher and students" (p. 89). Anneke's comment "But if it doesn't really matter . . ." is characterized as follows: "Anneke first expresses some doubt about the unfolding account of her peers" (p. 90), Doug notes that Anneke's earlier comment, "we think" "builds uncertainty into their collaborative turn" (p. 90), and that "for the first time in the sequence, a student is addressing her peers, and not Rich." A comment by RL is interpreted as "a question that becomes a next occasion for Anneke to express her doubts," (p. 90), subsequent turns are characterized as a proposal and a counter, and an assertion by Anneke is said to be "the direct expression of a disagreement" (p. 91).

In my understanding, Doug's analysis includes details about positioning that fill in aspects of interaction that were left unspecified in my analysis. In my view, Doug's analysis provides a mechanistic explanation. That is, he identifies products such as doubt, uncertainty, occasions for next turns, and disagreement, which are produced in interaction. I believe that in regard to interactional/systemic aspect of activity, the relation between his account and mine is that his mechanism sketch is less sketchy than mine. Although Doug characterized his account as descriptive and not explanatory, I believe it is valid to interpret the components of his account as hypotheses about mechanisms of interaction.

In most cases, I believe that Doug's hypotheses (as I characterize them) could be incorporated in gaps that I left in my account. One substantive hypothesis on which we may differ involves the functionality of RL's contributions. Doug's account (I would say hypothesis) characterizes RL's participation in terms of hints. "I want to say that the very best classroom teachers are very good at giving 'hints,' and that this is what Rich is doing throughout; giving hints and building the grounds for pursuing them, where hinting is a practical game of nurturing the conclusions of others. As it is exercised here, hinting yields agreement" (p. 93). My interpretive hypothesis is that RL's contributions provided direction to the group, for example, that his question "How does it help you answer your question?" [Excerpt 5, 0:41:05] was understood as a rhetorical direction, albeit not by stating explicitly what the students should do. Doug's account and mine require some resolution. It could be that the concept of a hint and the concept of rhetorical direction (rather than explicit direction) are compatible, that is, both hypotheses are valid, identifying functions that both can be accomplished with the same utterance. But if this is so, I expect that this meaning of "hint" should be distinguished from another sense, where a hint provides assistance in finding something, such as an approach to solving a problem, that is not evident to the person or people receiving the hint.

Although there is this discrepancy in our hypotheses (and there may be others) I believe that the substantive contents of our accounts could be combined – that is, they are not only commensurate but they are largely compatible. And we have a difference at the level of metatheory, involving explanations and hypotheses.

At the level of metatheory, I hope that I have made a case that there is a version of the concepts of explanation and hypotheses with which Doug's and other ethnomethodological accounts are compatible. If I have succeeded, then I believe that we can count our two approaches as being more commensurate than Doug's account makes them out to be.

At the level of theoretical substance, I welcome Doug's detailed analysis of the development of disagreement and, then, agreement in the students' and RL's interaction, which I judge to add significantly and valuably to the sketchier account I gave in terms of positioning. At the same time, I also believe that my interpretations of products of their interaction, which I characterized as hypotheses about states of affairs that came to be included in the participants' common ground, could be added to Doug's analysis without harming the content of his account. What these amendments would add, I believe, would be explicit (in my view), hypothetical accounts of what the participants' agreements and disagreements were about. I do not suppose that the addition of hypotheses about the states of affairs in common ground, and how they got there, are a simple addition to the kind of ethnomethodological analysis that Doug's account provides. I agree with Doug's view that information structures are not, in some sense, logically or causally prior to activity. Instead, I believe that information in the form of states of affairs is constructed in the process of interaction. So is positioning. The attempt to specify and explain both the dynamic construction of states of affairs in common ground (the semiotic products of activity) and the dynamic construction of positioning (the systemic aspects) is more ambitious than either the cognitive effort to specify and explain only the semiotic aspects or the ethnomethodological effort to specify and explain only the systemic aspects. In the kind of integrated explanatory accounts that I believe we can achieve, hypotheses about both aspects of interactive processes and mechanisms are included in the accounts we can give of either kind of product.

Response to Collins

I thank Allan Collins for his supportive response to my effort to begin to understand intellective identities.[6] I also appreciate his discussion of representational and metarepresentational competence and their importance in learning in subject-matter disciplines. I add, consistent with the general effort to attend to both systemic and semiotic aspects of activity, that analyses of constructing, using, and learning with and about representations are an important research topic in the situative perspective, where they are considered as practices of a community or continuing activity system, such as a classroom.

Analyses of representational practice of this kind have been conducted, especially, by Hall and his associates (Hall, Stevens, & Torralba, 2002; Hall, Wright, & Wieckert, 2006). Their analyses develop a concept corresponding to meta-representational competence at the level of communities of practice, which they call representational infrastructure. Becoming competent and effective as a participant in the intellective practices of a community or continuing activity system includes becoming a capable participant in its representational practices, using its representational infrastructure; and curriculum resources and activities can be designed with learning representational practices as an important focus (Greeno & Hall, 1997).

Collins discusses some features of different forms of graphical representations that make them particularly useful for displaying different features of data[7] and remarks, "I am not sure how a curriculum for graphing should develop systematically to capture the kinds of issues I am discussing here, while developing the kind of representational competence that Greeno is advocating" (p. 107). He also states, "... to teach representational competence effectively we need to create learning environments that give students the 'conceptual agency' to build upon their meta-representational competence to resolve the difficult issues around representation." (p. 110). Collins's observations seem valid to me. In response, I can offer a conjecture about design features that could provide students with opportunities to learn the semiotic practices of graphing while developing positive intellective identities. This conjecture is based on diSessa, Hammer, Sherin, and Kolpakowski (1991) study of a group of children who invented graphical representations of motion, along with Schwartz and Martin's (2004) study of activity in designing an index to represent variability in samples of data, as well as the example of activity provided by Lehrer and Schauble that we all examined in the chapters of this volume. In these activities, students worked on tasks of constructing representations to solve specified problems and, therefore, explored alternative ways of representing features of an event or a collection of data. These studies show that activity involving exploration of alternative representational practices, focused on solving a problem, can provide opportunities to learn, or prepare to learn practices that use specific forms of representation while being engaged with significant authority and accountability, thereby also having opportunities to develop positive intellective identities. What I believe I found in the analyses I presented is that the dance of agency in these settings is complicated, and does not yield to a simple characterization of what kind of agency students are positioned to have. Instead, we need to attend to the distribution of agency regarding different aspects of the activity (in the examples I analyzed, these were production of variation and resolution of differences) and consider consequences of those differences regarding both students' learning to participate in the activities both in its informational/semiotic and interactional/systemic aspects.

Response to Bredo

Eric Bredo's commentary clarifies the aims and means of my effort, concludes generously that I accomplished the aims that I took on (and did not accomplish some that I might have been thought to attempt), and supplements my argument by pointing to some matters that my effort does not reach. In his comments at the workshop Bredo correctly concluded that my aim is "to interrelate better content and control aspects [which I called semantic and systemic aspects] of group problem-solving," that I did not "[succeed] in integrating individual and social levels of analysis . . . since this was not really what he was attempting to do," and that from my analyses "we do not know the students' private beliefs or conclusions."

Although I have not taken up the task of integrating individual and social levels of analysis, I do have a thought about a kind of analysis that could move in that direction, and since Bredo opened this door, I can mention it by way of clarifying what my position paper tried to accomplish and what could be a direction of further progress. I believe it is a mistake to assume that some cognition and learning is individual and some is social. Instead, I believe that the distinction between individual and social cognition and learning is in the minds of analysts, corresponding to the units of analysis that we adopt. That is, the same events involving cognition and learning can be analyzed either as activities of a system involving individual persons and other components in interaction, or as activities of a single individual with other persons and other components as contexts of that individual's activity. As Bredo points out, the analytical concepts in the middle column of Table 3.1 have been developed with the analytical focus on individuals, and the concepts in the right column have been developed focused on interactive groups.[8] And as he correctly concluded, my theoretical proposal is to relocate the cognitive concepts and consider them (with suitable adaptations) as aspects of the functioning of activity systems, usually (though not always) involving groups of people in interaction with other material and informational systems. I see the project of developing a situative theory to be developing a coherent and comprehensive explanatory system with cognition and learning treated as functions of activity systems. If we succeed at this, it will not preclude continued development of a coherent theory in which cognition and learning are treated as functions of individuals, with other persons and material and informational systems treated as contexts. This theory includes hypotheses about the "private beliefs or conclusions" of individual students, along with hypotheses about their strategies, schemata, and other cognitive characteristics. As we develop both of these theories, we should attend to the goal that they should be coherent with each other. To the extent that we accomplish that, we will be achieving integration of the individual and social levels, which Bredo correctly noted that I did not undertake. However, by appropriating concepts and principles of individual cognition for the system-level situative theory, I hope that the task of integrating the two levels may be facilitated.

Response to McClain

Kay McClain's commentary correctly argues that my paper neglected important functions of teachers in determining the agenda for their classrooms, including selecting the tasks that their students and they work on. McClain's criticism prompts me to realize that this chapter, along with my other recent work, is focused on issues in the first three levels of Table 3.1 in my chapter. I believe my examples do address some issues involving the roles of the teacher and task at the level that I refer to as "Practices that encourage problematizing and resolving and that position students in disciplinary discourse with competence, authority, and accountability in participation structures" (see Table 3.1). I did not address the important, more global, issues in which teachers are crucially important, of formulating aspired-to learning trajectories, constructing curricula of activities that can support progress along those trajectories, and evaluating the class's and individual students' progress in order to conduct activities as effectively as he or she can in supporting students' progress. These are issues of crucial importance, and their scope is broader than that of analyses like those of my chapter. It could be useful for us to think of them as issues in the organization of activity systems that are designed for learning.

I appreciate greatly McClain's comment that "It is here, in the field of teacher development, that I believe Greeno's work can have the most impact" (p. 130). I have mainly focused on studying and theorizing about student learning, and McClain's use of the theoretical frame that I have been working to develop provides an extension beyond what I have been able to do with it that is very welcome.

McClain interprets the levels presented in Table 3.1 as differences between levels of functioning, with higher levels more advanced. This is interesting, and different from my view of what the levels distinguish. My sense has been that the levels are analytical. That is, an analysis of an activity system can focus on issues at a finer or coarser grain size, and the levels in Table 3.1 are pointers to phenomena and explanatory concepts that characterize the system more finely or coarsely On this view, there are always aspects of functioning going on at all of the levels that the table presents, but what the group is doing, characterized at whatever level, might not be viewed as making positive progress. As I reread the table, though, I understand how McClain (or any reader) could interpret the higher-numbered levels as involving more advanced functioning. For example, it would have been a more accurate expression of my intention to describe level 3, on the situative side, as "Practices that encourage or discourage problematizing and resolving and that position students in disciplinary discourse either with competence, authority, and accountability in participation structures or position them in ways that lack these features."

I did intend for Table 3.1 to provide a characterization of analytical levels that could be used in studying learning and cognition by students in classrooms or for any other subjects of inquiry about learning and cognition, including teachers' understanding and learning in their teaching and other professional activities. I appreciate McClain's observation of the duality of teachers' knowledge, including both knowing in the subject-matter discipline and knowing in the activity domain of teaching that subject-matter domain. Part of their knowing in the teaching domain could be a schema for understanding the understanding and learning of their students – it seems likely that practicing teachers have such schemata. A possibility that would be positive for the scheme in Table 3.1, if it is true, would be if the levels presented there as alternative foci of analysis by researchers could be used in programs of teacher education or teacher development to frame intended trajectories of learning for teachers in those programs. It may be, at least in our society, that the issues I located at higher levels in Table 3.1 are less likely to be considered by teachers in evaluating and interacting with their students than the issues I located at lower levels. If that is the case, then it could be valuable to consider ways that programs in teacher education or teacher development could incorporate the aim of having their understandings of learning progress toward including those levels as well.

Finally, I need to respond to one of McClain's responses to my discussion, "I argue that it is the acceptance of the proposition as a *problem* and following up to reconcile the problem that leads to conceptual growth, cognitive development, and changes in discourse practice and that this is *not* dependent upon the source of the proposition" (p. 127). This may be true for many aspects of what is learned, but it seems likely, at least to me, that if students are always positioned to respond to issues that the teacher makes problematic, rather than being positioned frequently to identify and present problems, there could be a difference in their learning to interact with the concepts and methods of the subject-matter discipline. Specifically, I believe that abilities and dispositions to generate alternative meanings and interpretations need to be learned, probably within disciplines, and that opportunities to learn to do that are provided when students are positioned to generate alternative meanings and interpretations to those that have already been presented by the teacher and textbook.

Notes

1. I have one correction to Doug's brief, helpful account of the development of a branch of the situative idea as I experienced it. Doug referred to "the later arrival of Jean Lave," subsequent to the founding of the Institute for Research on learning (IRL). Jean was a visiting scientist at Xerox PARC, on leave from U.C.Irvine, when the possibility of organizing IRL first was being discussed, and, along with Brigitte Jordan, Jean played a crucial role in conceptualizing and founding IRL in 1987.
2. My understanding has also been aided greatly by an exchange of email messages in which Doug expanded on some of the points he made in his commentary.
3. Technically, I consider the contents of common ground can be represented as states of affairs in the sense of situation theory (Barwise & Perry, 1983; Devlin, 1991).
4. I follow Peirce (1897–1910/1955) in assuming that a symbolic, iconic, or indexical sign has meaning only under interpretation, that is, symbols, etc., do not, in themselves refer to anything in the material or conceptual world; instead, designation always involves an interpretant that is someone's intended meaning of the sign. I also assume, following Clark and Wilkes-Gibbs (1986), that referents of symbols, etc., including interpretants, are products of conversational interaction that are included in the contents of common ground.
5. This is consistent with other contributors to the Conversation Analysis program. Schegloff (2007) put it this way: "Whatever may be the case about topics and topicality, it is important to register that a great deal of talk-in-interaction — perhaps most of it — is better examined with respect to *action* than with respect to *topicality*, more for what it is *doing* than for what it is *about*" (p. 1).
6. The paper that Collins cited has subsequently also been published as a chapter in Gordon & Bridglall (2007).
7. I think theses issues are clarified usefully with Stenning's (2002) distinction between reference that is understood by direct interpretation and reference that is understood by indirect interpretation.
8. I do disagree with Bredo's statement that these concepts "apply exclusively on the group level of analysis" (p. 119). In the situative perspective, an individual engaged in cognitive activity is considered as interacting with something, and if there are no other persons involved, the interaction may be with a computer program, or a text, and often with concepts and methods of a subject-matter domain. In the framework I wrote about in my position paper, it would be significant to hypothesize about how the individual is positioned in relation to the conceptual domain and the text, computer program, or whatever, what kinds of issues the individual problematizes in her or his interaction, and so on.

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Part III
A Dialogic Theory of Learning

Chapter 9
Saying More than You Know in Instructional Settings

James V. Wertsch and Sibel Kazak

It has long been recognized that analyzing instructional interaction is a complex matter and that insights will be generated only by harnessing a variety of theoretical and methodological perspectives. In what follows, we employ ideas about mediation and its role in organizing social and psychological processes. This approach is hardly the only one that could be used to examine the classroom interaction that is at the center of this volume, but we found it to be a perspective that yields some interesting new insights into this interaction.

The fact that the section of this volume in which our chapter appears has "dialogue" in its title might suggest to some that our focus on mediation is misdirected. However, as the reader will see, our account of mediation is inherently linked with dialogue since the latter is built around the former and the former emerges only in the context of the latter. In the excerpts of interaction we examine student-student and teacher-student dialogues are organized around mediational means, or cultural tools that are used at varying levels of dialogic intersubjectivity. So in a sense we could have presented our analysis as one having to do with dialogue rather than mediation. We have organized our argument around the latter, however, trying to employ what we take to be the most basic conceptual category in the writings of Vygotsky (cf. Wertsch, 1985).

At the end of our chapter we turn explicitly to the issue of alternative conceptual frameworks that could be employed to interpret instructional interaction. Specifically, we take up constructivism and propose that there are some complementarities with the mediation-based account we outline. This is intended to provide another reminder of the basic point we started with – namely that multiple theoretical and methodological perspectives will have to be employed if we hope to provide real insight into the kinds of social and psychological processes that go on everyday in instructional settings.

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In the last chapter of *Thinking and Speech* (Vygotsky, 1987) (sometimes mistranslated as *Thought and Language*), Vygotsky turned his attention to a semiotic phenomenon that had concerned him throughout his career: the relationship between form and meaning. The very title of this chapter, "Thought and Word,"[1] reflects this concern in general and how it plays out in connection with words or discourse in particular.

For Vygotsky, the key to understanding this relationship is to recognize that it takes the form of an opposition or dialectic that underlies the development of word meaning. His line of reasoning includes basic insights that are not always appreciated today and hence worth revisiting. He began by outlining the misguided notion that thought and word could be studied in isolation from each other, a notion that characterized much of the research of his time. Instead of studying these two elements as separate phenomena, he proposed using word meaning as a unit of analysis, a unit that encourages us to remember that it is "a phenomenon of both speech and intellect" (Vygotsky, 1987, p. 244).

Vygotsky emphasized throughout this chapter, as well as elsewhere that the dynamics of word meaning involve a struggle between thought and discourse, a struggle that he viewed as being at "the conceptual center of our investigation" (p. 245). This point was so central to his approach that he asserted, "The discovery that word meaning changes and develops is our new and fundamental contribution to the theory of thinking and speech" (p. 245).

Vygotsky took this claim to apply to "microgenetic," as well as ontogenetic forms of development, asserting that word meaning "changes during the child's development and with different modes of functioning of thought" (p. 249). Regardless of which "genetic domain" (Wertsch, 1985) is at issue, the general picture Vygotsky had was one in which thought is taken to be a relatively inchoate, "fused, unpartitioned whole" (p. 251) that comes into contact with words, which involve generalization and discrete, sequential representation.

This dialectic between thought and word was at the heart of what had concerned Vygotsky for several years leading up to the formulation of the issue near the time of his death in 1934. In fact, it was part of discussions in which he had engaged since the time he had been a student in the seminars of Gustav Gustavovich Shpet (1879–1937). An intriguing figure in his own right, Shpet was the focus of increasing repression in the 1930s and eventually was tortured and executed in the Siberian university town of Tomsk. Given his grisly fate and the direction in which the Soviet Union was moving in the early 1930s Vygotsky's failure to cite Shpet in his later writings is understandable. But the influence of this figure on many of Vygotsky's ideas, especially those developed in Chapter 7 of *Thinking and Speech* is clear.

If we trace this intellectual genealogy back yet further, we encounter the influence of two other major figures: Wilhelm von Humboldt and Edmund Husserl. Shpet's debt to the philological tradition of the former is evident in one of his most interesting and important works, *The Inner Form of the Word* (1927), which had the subtitle *Studies and Variations on a Humboldtian Theme*. And the influence of Husserl derived from some of the most formative influences on Shpet's intellectual life. As a young man he had traveled to Europe to apprentice with this great figure in phenomenology, and he maintained personal communication to the extent possible even into the early years of World War I. The influence of Husserl is manifest throughout Shpet's writings, and his first major work, *Appearance and Sense* (1991) is generally viewed as the work that introduced Russian and Soviet scholars to phenomenology.

This digression in intellectual history is worth making because it provides some insight into Vygotsky's claim about how word meaning develops. Although Chapter 7 of *Thinking and Speech* deals with several experiments and other empirical psychological studies, its main concern is a philosophical issue raised by Shpet, Husserl, and Humboldt. This intellectual heritage provides the context for understanding his claims about the dialectic between word and thought and the more general line of reasoning about the relationship between semiotic form and meaning.

From this perspective the dialectic involved is between a sign vehicle, or what Charles Sanders Peirce (1955) termed "the *material* qualities of the sign" (p. 234) and object-oriented intentions of speakers or listeners. It always involves an element of collision and conflict between a sign vehicle, whose meaning tends to abstract and generalize and belongs to an ongoing semiotic community, on the one hand, and the unique, spatio-temporally located intention of the individual, on the other.

This process has been described under the heading of "articulation" by Shpet (1927) as well as contemporary philosophers such as Charles Taylor (1985). Semiotic action, including saying something in ordinary language, typically involves an element of articulating, or breaking up a thought or intention into discrete, generalizing signs. In this view the thought or intention is something associated with an individual operating in a unique context and does not come in pre-segmented form. Instead, it is simultaneous and amorphous. The particular sign system (e.g., English, Russian, statistical notation) that we employ to articulate a thought imposes a particular organization on this thought, one that differs from other possible sign systems that could have been employed.

This view of the dialectic between thought and word, or more generally, intention and sign, has important implications for the analysis of socialization and instruction. These start with the underlying assumption that the outcome of instruction is "knowing how" rather than "knowing that" (Ryle, 1949; Bechtel & Abrahamsen, 1991). Specifically, it is knowing how to employ cultural tools such as language or mathematical techniques. This focus on the "mastery" of cultural tools (Wertsch, 1998) differs somewhat from our usual way of talking in which we speak of the need to understand or know concepts, and the different emphasis it brings has implications all the way down the line of reasoning that follows.

The goal of instruction from this perspective is to help students become fluent users of a sign system. The outcome is a sort of "distributed cognition" (Salomon, 1993) to use terminology from contemporary cognitive science. Namely, it involves distribution between cultural tools and the active agents employing them. From this perspective, instruction amounts to a sort of "taming" or "domestication" of novices' interpretations of the world. This domestication has both benefits and costs because cultural tools inevitably bring with them "constraints" as well as "affordances" (Wertsch, 1998). For example, learning to deal with a set of data by employing a particular statistical technique provides insight into patterns that would otherwise remain undetected, but it also entails being less likely to see other patterns that could be revealed by employing a different technique.

From a Vygotskian perspective, the process of mastering a semiotic tool is fundamentally social, though it, of course, has individual psychological moments and outcomes as well. In his "general genetic law of cultural development," Vygotsky made this point by arguing that higher mental functioning appears first on the "intermental" and then on the "intramental" plane. When encountering a new cultural tool such as a statistical instrument, this means that the first stages of acquaintance typically involve social interaction and negotiation, between experts and novices as well as among groups of novices. It is precisely by means of participating in this social interaction that interpretations are first proposed and worked out and hence available to be taken over by individuals.

One of the properties of the sign systems that are at the heart of instruction is that they are incredibly robust in that they can allow interpretation and understanding at many different levels yet still support the intermental functioning required to move learning and instruction along. It often seems to be possible to use these sign systems to communicate even with a very low level of shared understanding of their full implications. Indeed, most of us probably speak, calculate, and carry out other semiotic action most of the time without understanding the full power of the sign systems we are employing. In the famous image of Edward Sapir (1921), it is as if we are harnessing a dynamo capable of generating a huge amount of electricity just to power a doorbell.

An implication of this approach is that it is possible for students who are novices at using a particular sign system to begin to use sign vehicles without understanding all that much of their meaning, at least in the way it is understood by competent users. This appears to be counterintuitive when considered from the perspective we usually employ in Western social science. The reason for this is the implicit commitment to methodological individualism that underlies so much of what we do. From this perspective, it is impossible for a speaker to say something if she does not first have a relatively clear and articulate idea. From such a perspective, meaning and understanding are properties of the individual rather than of a dialectic between active agent and cultural tool.

The "Vygotsky-Shpet" perspective we are outlining suggests that something fundamentally different is often involved. Namely, the act of speaking often (perhaps always) involves employing a sign system that forces us to say more (as well as perhaps less) than what we understand or intend, more in the sense that interlocutors may understand us to be conveying a higher level message than our mastery of the sign system really justifies. This is so in everyday communication, even when we are speaking about topics on which we have developed real expertise, but it has particularly important implications when it comes to how novices participate in intermental functioning in instructional settings.

The notion of "intersubjectivity" provides another useful part of a framework for dealing with these points. This is a notion that has been explored by figures such as Ragnar Rommetveit (1974, 1979) in connection with human communication in general and Barbara Rogoff (1990) in connection with human development and socialization in particular. Interestingly, part of Rommetveit's intellectual heritage comes from the phenomenologist of social life Alfred Schutz (1951), so it would appear to be no accident that his ideas on intersubjectivity are compatible with a Vygotsky-Shpet perspective. Rommetveit (1979) has provided the following illustration of this phenomenon:

> Imagine the following situation: A lady who is a very knowledgeable amateur auto mechanic discovers that there is something wrong with the carburettor of her car. Her husband, who is notoriously ignorant about car engines and does not even know what a carburettor looks like, offers to drive the car to a garage to have it repaired. He tells the car mechanic at the garage: "There is apparently something wrong with the carburettor." This saves the latter considerable time in searching for the problem. (p. 102)

For Rommetveit, the point is that the husband in this case may have attained only a very minimal level of intersubjectivity with the mechanic when it comes to understanding the idea and function – and even the referent – of "carburettor." However, he was still capable of passing along the message from his wife because he was harnessing a sign vehicle that did part of the work for him. As Rommetveit notes, instead of assuming that the husband possessed the understanding that could fully back up this utterance, he was involved in an episode of "ventriloquation" that allowed him to say more than he understood.

The point of Rommetveit's example is not to encourage us to go about using expressions for which we have only a minimal understanding. Indeed, his example is clever precisely to the degree that it manages to do something unusual in this regard. In socialization, learning, and instruction, though, the point of many exercises may be to put us in a position not unlike that of the husband in this illustration. The standard situation in many instructional settings involves students' saying and doing things that they only partially understand. This raises what might appear to some to be a paradox of how it is possible to say more than one understands, but it makes sense if one recognizes that the material form of sign vehicles allows us to function at a level that is "out ahead" of our current mastery.

But the point for instruction goes beyond this. Not only may it be possible, but it may be *desirable* for students to say and do things that seem to extend beyond their level of understanding. This is because such a possibility means they can enter into a basic form of intersubjectivity with more experienced teachers and experts and thereby leverage their way up through increasing levels of expertise. What might at first appear to be a failure to communicate is often the key to entering into a new area of instruction.

Methodological Challenges

The ideas of Vygotsky, Shpet, and others are often viewed as insightful and interesting, but the implications of these ideas for empirical research are not always obvious. This should perhaps come as no surprise, given that Vygotsky was influenced by phenomenology, a school of thought that resists usual positivist analyses based on relationships between independent and dependent variables and so forth. Instead of trying to formulate things in such terms, it would seem that some sort of textual and discourse analysis would be appropriate as an approach to empirical research, and that is what we propose here. To be sure, this sort of approach can – and should – be complemented by others that involve controlled experimentation, large scale quantitative analyses and so forth.

The basic issue for empirical research in the Vygotsky-Shpet framework we have outlined is to determine how well subjects have mastered a word or other semiotic means. What sort of evidence can we muster to assess whether someone knows how to use words, statistical techniques, and so forth? How domesticated is their thinking and how fluent and appropriate is their mastery of these means? These are the kinds of questions that arise from such a perspective, and the answers would seem to be found in fine-grained analyses of the processes involved in intermental and intramental functioning. This means looking for evidence about whether a student is using a term or other semiotic means appropriately or responding in a way that suggests they understand the use of the term by another speaker.

The biggest problem that emerges in this regard is typically that investigators cannot be certain just how much students understand when they use, or respond to a term, even when that use or response seems to be appropriate. This follows from our earlier claims about the robustness of these terms. What makes methodological sense when using this perspective is to employ a conservative measure that gives credit to a speaker or listener for no more than the minimal understanding that is required to use or understand a term in the particular case. It is relatively easy to identify when students use or respond to a term *inappropriately*, and this certainly provides another major source of evidence. What is less clear and more difficult, however, is knowing when to credit someone with genuine mastery of a cultural tool.

Mastering Semiotic Tools in Instructional Discourse: Illustrations from Statistics

Illustration 1: Teacher–Student Interaction

In an attempt to harness – as well as further develop – the ideas outlined so far, we turn to analyzing two episodes of interactions that occurred in a science classroom discussion. This discussion began by asking students to look at some data collected from the Fast Plants under the same amount of light as part of an earlier experiment about the effect of different levels of light on the growth of plants. More specifically, the discussion concerned how to organize the height data from the Fast Plants. In Excerpt 1 in Appendix B, classroom interaction started as follows:

Excerpt 1 [0:00:07–0:00:28]

```
0:00:07 teacher:  And what we want you to do: is (0.4) we're
                  going to give you a piece sheet of graph paper
                  (0.8) and I want (0.5) you to organize the
```

```
                     data (0.3) some way. (1.5) Ahm:: (1.1) and
                     eventually what we're going to do with that
                     data is we're going to have you: (0.6) ahm::
                     the kind of thing before with rockets (0.9)
                     ahm: (0.9) and I know Rich you had a question,
0:00:28 RL:          Ahm (how spread out are the) fast plants, at
                     day nineteen.
```

Following some discussion about how the data were recorded, the teacher posed two questions to answer after organizing the data: (1) "What is the typical height?" [0:01:14 – 0:01:29] and (2) "How spread out are the heights?" [0:01:55 – 0:02:14].

For the teacher or anyone else with any level of expertise in analyzing data of this sort, there are at least five obvious clues as to what is expected here. First, teacher gave the students graph paper. This paper qualifies as a cultural tool (specifically, a sign vehicle) that can be used to help individuals organize and summarize their data such that patterns become more obvious. This is a cultural tool that encourages individuals to take advantage of their powerful visual perceptual processing capabilities for understanding patterns in the world, but in order to afford this possibility, it must be used in an appropriate way. Second, he specifically mentioned that he wanted the students "to organize the data some way" [0:00:07]. He did not tell them which way, but he assumed that the graph paper affords certain possibilities of doing so that will help them see patterns. Third, the more obvious clue later was "eventually what we're going to do with that data is we're going to have you the kind of thing before with rockets" [0:00:07]. However, there was no mention of this task with rockets and how it might be relevant to the task at hand again later. Fourth, teacher mentioned that he wanted the students to determine what the typical fast plant height is [0:00:14 – 0:01:27]. In this context, the term "typical," a term he repeats several times in what follows, has a special meaning. Namely, it points to a measure of the central tendency of a data set. And fifth, he told the students they should be asking about "how spread out" the data are (see [0:01:55 – 0:02:14], also Fig. 22.2). In this context, the notion of being spread out reflects a concern with what is called the variability of data in the language of statistics.

In the discussion that follows, it becomes quite clear that, at least initially, the students' understanding of how to use graph paper and how to organize the data, as well as their understanding of the terms "typical" and "spread out" have little overlap with that of the instructors. For example, Group 3 composed of Tyler, Kendell, Edith, and Jasmine initially proposed to put one number from their data set in each square on the paper (see Excerpt 4). This seems to have been their first attempt to respond to the directive to "organize the data."

To be sure, these students were using the sign vehicle provided to them, but they clearly did not know how to use it as an expert would. Their performance was in some sense distributed between themselves and the cultural tool, but they were using this tool at a very low level of sophistication, one that might simply be termed inappropriate. In this sense, their use (misuse?) of the cultural tool bears a striking resemblance with young children's use of cards as memory cues in Leont'ev's "forbidden colors task" (Vygotsky, 1978).

In this context the group instructor, LS, noted, “So it looks like the numbers will go from thirty to two fifty five” [Excerpt 4, 0:20:51]. Jasmine then said that the chart they were making could go from one to the biggest number, and LS pointed out that they could not get this on the graph paper they have (presumably along the horizontal axis).

Up to this point the graph paper has served as a material sign vehicle that is interpreted at quite different levels by the participants in the conversation. The students are using it at a primitive level and see it as providing a set of blank spaces to be filled in with an ordered set of numbers. Why they are doing this is unclear – apparently to them as well as LS or anyone else, but the graph paper does serve to impose some organization on the processes they are carrying out and hence is serving as a cultural tool that at least serves as a common material object of focus for the students and the instructor.

Even at this primitive level of understanding and intersubjectivity, LS was able to take advantage of the cultural tool to impose some order on the task by pointing out that the range of numbers in their data would not fit on the graph paper. Her move took advantage of this cultural tool to rein in the students’ seemingly aimless wandering and was an attempt to push their thinking to a higher level. An indication that they did not really know what they were doing up to that point – and realized this – can be found in the fact that they immediately gave up on their first proposed use of the graph paper. This suggests that they were using the material form of this cultural tool but understanding very little in the way of how it could help organize their activity in a socioculturally appropriate way.

At this point, LS posed the question, “So if we wanted to show numbers from thirty to two fifty five on this page, what would we be thinking about? How many numbers do you have to cover from thirty to two fifty five?” [0:21:24]. Jasmine has responded by pointing to the numbers recorded on the board and answering, “Sixty three that are on that sheet over there” [0:21:49], indicating that the level of intersubjectivity between LS and herself was still quite low. Again, however, it is worth pointing out that the relatively low level of intersubjectivity that had been attained at this point was possible because of the robustness of the semiotic means they were employing. Without attaining *some* level of intersubjectivity, there is little hope of leveraging it to a higher level in such cases.

At this point, the instructor provided uptake to Jasmine’s response by using part of it as a “thinking device” (Lotman, 1988) and turning it into the next instructional question she posed, “What was our range of values there? You know sixty three numbers, but they go some thirty to two sixty five so [how much do they span?” [0:21:52]. And to this, Jasmine responded, “Two twenty five” [0:22:00]. This interchange took the form of an I-R-E sequence (Initiation by teacher, Response by student(s), Evaluation by teacher), with all its pluses and minuses. On the one hand, this sequence served to give rise to an answer (one that is getting closer to an expert’s understanding of the setting), but on the other hand, this answer was backed up with very little understanding of what function it served. Jasmine could answer the instructor’s immediate question, but she demonstrated very little understanding of why LS was asking the question and where she was going, providing additional indication of a low level of mastery of the cultural tools being employed.

Jasmine's response at this point indicated that she was continuing to focus on the number of points in the data, not the range of values. This confusion, or misunderstanding of the proper use of the graph paper, continues into the next stage of interaction. There, LS pointed out, "So, somehow we gotto show two hundred twenty five numbers on the paper" [0:22:05], and in response Jasmine, Edith, and Tyler collaboratively computed how many squares were on the graph paper, apparently in order to determine whether there were enough for their data. The students seemed to take LS's prompting at face value, rather than to develop a scale for the abscissa. When she realized that they were calculating the number of squares on the graph paper, LS finally asked them what they were doing and responded by noting, "Well, we don't want to know how many squares we have altogether right?" [0:23:29].

Realizing that the students still were not using the cultural tool they had been given in the appropriate way, the instructor finally asked them to reflect on what they were doing, saying, " Well now wait a minute let's stop a minute and think about what is it that we want to show. We know we have these numbers, we know they go from thirty to two hundred and twenty five, what would be a good way of showing our data so that we can look at it and say oh I kinda have a sense" [0:23:45]. This increasingly more direct form of "other-regulation" (Wertsch, 1985)[2] still does not result in the redefinition of the students' use of the graph paper to represent data values rather than data points. One student made this obvious by noting that they had more than enough squares on the paper to show their data.

At this point, some 24 min into the session, the instructor switched from using questions and other forms of indirect other-regulation to encourage the students to see her point to an explicit proposal for how the graph paper should be used. She explicitly and directly proposed, "What if we did something and we had one square and we said lets put all the ones in there that go from this to this and then every number that was in that value we'd put a little X you know like the frequency charts we did?" [0:24:24]. The dialogue begins with Edith's "Oh" [0:24:35], followed by a pause, later suggests that the students still try to understand the assigned task (i.e., how the graph paper could be used as a cultural tool to get at the issues of central tendency and variability) and work it out as they proceed.

The instructor did not leave things at this, however. She moved on ahead with more concrete suggestions about grouping the data points together (e.g., values from 30 to 50) and marking the values in that range. Building on LS's suggestions, the group initially discussed whether the range for each square should be 20 and then decides on 10:

Excerpt 4 [0:25:55–0:26:18]

```
0:25:55 Edith:      Okay. We could- yeah we could do that.
                    ⌈Yeah that's (.) that's a good idea.
0:25:58 LS:         ⌊Well that's one way of doing it but I don't
                    know if it makes sense to you guys?
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0:26:01 Edith:     It makes sense to me:.
0:26:02 Tyler:     Oh I get it!
0:26:04 Tyler:     So yeah yeah what so
0:26:07 Tyler:     ((theatrically collapses on table))
0:26:10 Jasmine:   • hhh hahaha
0:26:11 Kendall:   TYLER, okay we have ten:
0:26:13 Tyler:     Like so the ones like (.) you said- you write
                   one through ten?
0:26:18 LS:        Yeah ⌈(           ) like that.
0:26:18 Tyler:         ⌊Like all the ones one through ten you
                   put Xs for?
```

In accordance with our comments about methodology, one cannot be certain how much the students really understand the setting and the use of cultural tools at this point, but they are clearly much closer to an expert's perspective than they had been earlier in the session. More specifically, the students' competence in organizing data evolved from simply showing each data value in individual squares on the graph paper towards grouping the data values in equal-sized bins.

Illustration 2: Student–Student Interaction

The second episode we examine involves students from Group 2 acting together but without intervention from a teacher, and the focus is again on how they use the sign system provided to them. This group is made up of Jewel, Anneke, April, and Wally. On Day 1, the group discussion was initially about the orientation of the axes of the graph paper (see Excerpt 3). A minute or so into the debate over which sides (long or short one) of the paper should be the x- and y-axes, Anneke noted, "Wait a minute! Wait a minute! How many numbers up there?" [0:11:35] and then Jewel responds, "Sixty something" [0:11:40]. This led them to discuss how many data points they needed to account for, and Anneke said, "Okay, could you put sixty three things across here?", pointing along the short side of the paper [0:11:41].

Later, like the students in the episode examined above, these students proceeded to count the number of squares on each side of the graph paper, an approach that suggests that the focus of discussion was on the capacity of each axis to accommodate data points.

While constructing the axes on the graph paper, Jewel pointed out the range of the values in the data. To her question, "Can you make two hundred some right here?" [0:15:00], April responded, "There are sixty three" [0:15:06], and Anneke added, "This is sixty-three" (pointing along the vertical or y-axis) "and then you have all the numbers" (presumably the numbers from 30 to 255) "goin' up this way" (pointing along the horizontal or x-axis) [0:15:08]. After that, the students discussed the capacity of the graph paper to accommodate the range of data points on the x-axis. In this discussion April pointed out, "That's a hundred and that's like half way [on the x-axis] so we could fives. Two hundred. We can do fives" [0:15:18]. This was the first time one of the students made a proposal correlated with a new insight as to how one can fit the range of values in the data set by selecting an appropriate unit of scale on the corresponding axis.

Later, an interchange occurred between the students and instructor, RL, who arrived to see what this group was doing (see Excerpt 5). The questions posed by RL seem to have initiated a new level of intersubjectivity between the students and the adult. The conversation began with relatively straightforward questions about how the graph generated by the students represents the plant height data. RL first noted the scale on the x-axis (by 8s, such as 30 to 38 to 46 and so on) and then asked them to explain their graph as he had some difficulty in understanding it. Apparently, their first attempt to organize the data set involved a line chart where they could place the plant heights (range of values from 30 to 255) on the x-axis and the plant numbers (sixty-three plants) on the y-axis.

Right after RL's final comment, "Oh, you are gonna have, so you are gonna have sixty three different plants here" [0:40:15], Anneke noted, "Does it matter? You are trying to figure out those two answers. And it doesn't matter what the names of forty six. The plants are in those. So couldn't you just put data from like Day 19? Couldn't you do that?" [0:40:20].

In response to this, Jewel remarked that they had to organize the data. Based on what the students have said and done up to this point, it seems that they are far from fully understanding what "organizing the data" means. At this point, RL reflected on what they are trying to do, saying, "Let's say that first plant, I'll call it Plant One, and I look over I am going to call one hundred and fifty nine, Plant One. And then I look over there and I see a one hundred and sixty five, that's Plant Two?" [0:40:50], and posed the question, "How does it help you answer your question?" [0:41:05].

Eventually, a new level of intersubjectivity seems to emerge as the students realized that plant height data were not ordered by numbers, such as Plant One, Plant Two, and so forth. However, Jewel's question, "But so how are you organizing it if I write in one sixty-three, one sixty-four, one sixty-five?" [Excerpt 5, 0:41:36] indicated that they were still struggling with the question of what it means to organize the data from an expert point of view. At this point, RL moved away from the group saying, "Well, you gotta kinda figure out what you are trying to figure out, Okay, so fix it" [0:41:44]. Finally, realizing that their initial line graph would not help them organize the data in a way that responds to the two questions posed by the teachers, April and Jewel agreed with Anneke's idea of "bar graph" because it allowed them to order their data from lowest to highest and stack them by their values, such as stacking 70, 71, 75, and 79 above 70 on the horizontal axis. Later, the idea of "bar graph" developed into a somewhat "stem-and-leaf" graph.

At the end, the final graphs created by the students in the two episodes discussed above had similar features. For example, in both graphs, students first ordered the data from lowest to highest on the horizontal axis and then stacked each data value. When showing the individual data in stacked form, bins (i.e., 70–79) and stems (i.e., 70 containing values from 70 to 79) were used in the histogram-like graph (see Fig. 2.8) and the stem-and-leaf-like graph (see Figs. 2.3 and 22.2) respectively. These two representations were comparable to a conventional graphical display of data frequency in bins.

Conclusions

The preliminary and partial analysis of classroom interaction that we have provided is intended to illustrate a few basic points about the Vygotsky-Shpet approach to instruction and learning. The first of these is that the goal of instruction from this perspective is to encourage students to master the use of cultural tools. Success is reflected in the ability to use these tools flexibly and fluently, and it involves a form of distributed cognition, one that involves active agents' use of semiotic means.

Given that the goal is to socialize students to use socioculturally provided and sanctioned semiotic means, the issue is how to engage them in a way that will lead to increasing levels of expertise. We have discussed this in terms of how it is possible to create initial levels of intersubjectivity when interlocutors have much different levels of understanding of what the task is and how to leverage that to higher levels of intersubjectivity and expertise.

In this particular instance, the cultural tool involves a complex mix of items. On the one hand, the students and LS used the graph paper, which by itself imposes various degrees of organization on their activity. But there are many things one could use this graph paper to do, reminding us that another crucial part of the cultural tool has to do with understanding how to generate histograms or stem-and-leaf graphs. These serve to organize data such that it is made available to powerful and efficient human visual processing capabilities, a technique that lies behind other strategies involved in calculation as well (Rumelhart, Smolensky, McClelland, & Hinton, 1986).

When using the graph paper in this context, two things become quite apparent. First, it is a cultural tool that allows novices and experts to enter into intermental functioning even when the two parties understand the task in very different ways. It is in this sense that the graph paper is a very robust material sign vehicle. It allowed LS and the students in Illustration 1 and another group of students in Illustration 2 to begin a discussion of what to do with the sixty-three data points at a very low level of intersubjectivity. But it is precisely this that then made it possible to move on to increasing levels of shared understanding of the data and how they are to be analyzed.

In the terms we introduced earlier, by working with the graph paper as a sort of mediator between different levels of understanding of the task at hand, LS was gradually able to domesticate the students' wide-ranging thoughts in this context. At one point she cleverly pointed to limitations that seem to exist in the graph paper itself, and this seems to have been sufficient to get the students to move away from one intention they seemed to have had. For the most part, however, she used increasingly explicit directives to guide the students' ideas, but she constantly negotiated this by harnessing the graph paper as a cultural tool.

On the one hand, this process could get off the ground only because the robust nature of this material sign vehicle offered possibilities for establishing intersubjectivity at very low levels. On the other hand, this sign vehicle provided the means for LS to introduce increasingly complex notions of central tendency and variation that are evident upon visual inspection of the histogram, so the whole process was characterized by increasing levels of shared understanding of how to use a set of cultural tools. Similarly in Illustration 2, the graph paper allowed students to coordinate their discussion around a cultural tool that offered only limited and partially shared interpretation of the data. But it was this primitive representation that then made it possible for RL to begin a discussion with them that resulted in a higher level.

A theoretical tradition that has had a powerful impact on instruction in science and mathematics is constructivism, and it is worth ending with a few comments on how our analysis fits with this school of thought. In one sense, the Vygotsky-Shpet approach stands in opposition to constructivism because it focuses on the notion that human socialization involves mastering the cultural tools that are provided by a sociocultural setting. Becoming adult means being socialized into an existing social order, characterized by an existing set of cultural tools. From this perspective the bottom line is that no amount of exploration on the part of novice students will yield the discovery of things like graph paper and histograms. These are historically evolved cultural tools, and the goal of instruction is for students to acquire mastery of them.

On the other hand, a great deal of the negotiation of meaning and intersubjectivity involved in our example looks like the kind of processes that are of interest to constructivists. Although the students did not discover graph paper or histograms, they did not simply have them passed on to them or somehow implanted in them in readymade form. Instead, they discovered a great deal of the meaning of these cultural tools through active exploration. In this sense, it seems to us that constructivism has a great deal to offer and indeed addresses a weak point in Vygotskian theory. The assumptions that seem to characterize some of Vygotsky's writings about standard, old style, didactic instruction may have had more to do with the setting in which he lived and worked than with any theoretical desiderata.

The resulting picture is one of *socioculturally situated constructivism*. In order for instruction to be maximally successful, there must be room for the active construction and negotiation of meaning on the part of students. But this construction is viewed as occurring within the confines established by a set of semiotic means that have emerged in a sociocultural setting. From this perspective, students are invited to discover the meanings that can be worked out when using certain sign vehicles, but they are not invited to discover cultural tools themselves.

All this raises several basic issues of practice. What sign forms are most useful and appropriate for creating a baseline of intersubjectivity in instructional settings? How can we recognize the interpretations and misinterpretations of these sign forms that novices are likely to bring to the table? And what forms of intermental functioning are most likely to push novices to the next level of expertise? In many respects these are standard questions for anyone interested in instruction and its improvement, but the insight brought by the Vygotsky-Shpet perspective is that instruction may be possible precisely because we can say more than we realize in instructional settings.

Notes

1. While "thought" in this case is an appropriate translation of the Russian term "mysl'," the other term in the opposition, "slovo," can be translated as "discourse" as well as "word," something that points to the active, processual nature of the semiotic phenomena Vygotsky had in mind.
2. While "indirect other-regulation" to students requires them to recognize and perform the implicit sub-steps in a task, in the use of "direct other-regulation" students are guided through the steps of solving a task.

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Chapter 10
Schooling: Domestication or Ontological Construction?

Martin J. Packer

The growing adoption of a sociocultural framework for the study of learning and development has met with some opposition, notably from those who see in it a lack of attention to the child's active construction in these processes. This, so the claim goes, is a central tenet of constructivism – whether that of Piaget (e.g. 1937/1955) or of von Glasersfeld (e.g. 1993) – even though it is granted that constructivism has not paid sufficient attention to culture, so that what is needed is a "synthesis" with socioculturalism. Such syntheses have been offered by Greeno (e.g. Greeno & MSMTAPG, 1998) and by Cobb (e.g. Cobb & Yackel, 1996), among others.

Wertsch and Kazak (Chapter 9) offer us another such synthesis, in the form of a "socioculturally situated constructivism." They explain its principle premise:

> In order for instruction to be maximally successful, there must be room for the active construction and negotiation of meaning on the part of students. But this construction is viewed as occurring within the confines established by a set of semiotic means that have emerged in a sociocultural setting. From this perspective, students are invited to discover the meanings that can be worked out when using certain sign vehicles, but they are not invited to discover cultural tools themselves. (p. 165)

I have argued (Packer & Goicoechea, 2000) that neglect of children's active construction in development is not in fact a failing of sociocultural theory or research. That some constructivists see things this way is a consequence, we propose, of the difficulty of dialogue and understanding across a chasm between incommensurate paradigms, which of necessity share very few basic assumptions. At the same time, some formulations of socioculturalism have made, as it were, only a partial leap. Socioculturalism – appealing to Vygotsky rather than Piaget, and hence to Hegel rather than Kant – rests upon a non-dualistic ontology which is quite distinct from the subject-object dualism of constructivist theory and research. Because this ontology is unfamiliar, even peculiar at first glance, it has often gone unnoticed and sometimes been resisted. Certainly it has not been recognized by most constructivist critics.

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Packer and Goicoechea (2000) suggested that what is needed is not a synthesis of constructivism and socioculturalism but their reconciliation, in which we take constructivism as adequate for specific cultures and times. Constructivism assumes a split between subject and object which is a product of particular cultural conditions. In short, it presumes an alienation of knower from known. Having presumed this split, it cannot explain it. Socioculturalism, in contrast, can explore and explain the cultural and historical circumstances that give rise to this condition, in which mental activity is accorded higher status than the embodied practical activity that makes it possible.

When Wertsch and Kazak write of a construction by children that can operate only "within the confines" of adult expertise, a construction limited to "the meanings" of cultural tools "but they are not invited to discover cultural tools themselves," they are indeed, I will argue, presuming this alienation. Piaget viewed children's construction of mathematical and scientific knowledge as active, but at the same time as constrained by the confines of logical necessity (hence he considered its outcome to be singular and universal). Piaget's is ultimately an unconvincing account (cf. Rotman, 1977) and we need an alternative, but I will argue that Wertsch and Kazak's synthesis does not fit the bill. In their version of synthesis the child's activity is once again seen as needing to be constrained for development to occur, constrained this time not by an ahistorical logic but – disturbingly – by adult power. Wertsch and Kazak have given up too much, I will argue. They have abandoned reason for "mastery."

One of my goals in this commentary will be to argue that the children shown in the Wisconsin Fast Plants® videos are indeed engaged in active construction, and that to fail to take account of this is to offer only an incomplete account of classroom learning. But I will propose that the kind of construction we can observe in these videos is not the epistemological construction that both neo-Piagetians and Glaserfeldian radical constructivists conceive of as the core of learning. It is an ontological construction, in which both known objects (mathematical objects) and knowing subjects are constructed.

To lay out this argument my commentary on the chapter by Wertsch and Kazak will focus on three points which are of central significance. The first is their broad assertion that schooling is a matter of "domestication" or "taming" (p. 155). I will point out several undesirable implications of this conception. The second is their claim that the instructional activities shown in the video-recordings provide an illustration of the classic situation where the adult is an expert, the child a novice, and learning is a matter of the expert guiding the novice. I will point out that the group of children working without adult assistance make considerable progress, while the assisted group does not make the progress attributed to them. The third is their claim that in this mathematics classroom activity the graph paper is an artifact that functions as a "material sign vehicle" (p. 160) permitting, as Wertsch and Kazak put it, interaction even with a low level of intersubjectivity, enabling the children to "say more than they know" and providing adult experts with "leverage" to move the children to a higher "levels of shared understanding" (p. 164). I will propose that the artifact does not have a single appropriate (expert) use, and that a conflict between "preferred representations" gives the children little choice but to concede to adult authority. I will then sketch an alternative account of this classroom task as the construction and transformation of a sequence of objects in the activity of children, adults, and academics. Finally, I will offer some remarks concerning the use of Vygotsky's work without doing violence to its intimate links to time and place.

Schooling as Domestication?

The core element of Wertsch and Kazak's account of learning becomes evident early in their chapter when they propose that "instruction amounts to a sort of 'taming' or 'domestication' of novices' interpretations of the world" (p. 155). This follows, they suggest, from the fact that the goal of schooling is "to socialize students to use socioculturally provided and sanctioned means" (p. 164).

Several problems are immediately apparent in this formulation. First, schools have been different things at different times and places and will continue to be, quite rightly. Any general and universal claim about schooling risks being ahistorical and acultural, which is not something desirable of a sociocultural theory.

Second, to aim for "domestication" would surely be to place tradition above innovation, and to fail to distinguish cultures that seek merely to reproduce themselves from those which seek to transform themselves. And, thirdly, in many places and times schools have indeed been charged with the task of "domesticating" children, especially from minority groups, who have been viewed as lacking culture, rationality, or morals, and as steeped in primitive, wild, or unenlightened belief systems. We cannot, surely, rid ourselves of such prejudice by extending this domestication model of schooling to all students.

Fourth, the "domestication" view of schooling, with its implication that children are "savage" and must be "tamed," seems to invoke precisely the "enculturation" conception of development that critics of socioculturalism have accused it of (e.g. Cobb & Yackel, 1996). It is hard to see what kind of place can be found in such a conception for the active role of the child as learner.

Fifth, viewing schooling as domestication and taming tellingly gives us no basis upon which to distinguish reason from faith, science from religion. There are of course those who assert that there is no valid distinction, that science is based on the religion of secular humanism, and that creationism should be taught in school alongside, or even replace, evolutionism. To concede this disagreement at the outset by dissolving the distinction between the appeal to a child's reason and the imposition on them of beliefs (or values, or conduct) through will – which "taming" surely suggests – strikes me as regrettable.

In short, the view that schooling is domestication has several unfortunate implications. How easily we can get rid of it, and what view we should replace it with, are matters whose discussion I will develop in the course of this commentary.

Novices Need an Expert?

The second aspect of Wertsch and Kazak's chapter that is important to examine is their claim that what we see in the classroom video-recordings illustrates the importance for learning and development of the interaction between expert and novice. Wertsch and Kazak put it this way:

> When encountering a new tool such as a statistical instrument. . . the first stages of acquaintance typically involve social interaction and negotiation, between experts and novices as well as among groups of novices. It is precisely by means of participating in this social interaction that interpretations are first proposed and worked out and hence available to be taken over by individuals. (p. 156)

In their analysis of the videos Wertsch and Kazak discuss both a group of students working with adult assistance (Group 3, Excerpt 4) and a group of students joined later by an adult (Group 2, Excerpt 3). Wertsch and Kazak describe both groups as illustrating the inability of students to deal adequately with their task without adult expertise.

Group 3, Excerpt 4: Novices Led by an Expert?

I'm faced with a problem of tact here, because I want to critique Wertsch and Kazak's analysis but it is difficult to do this without seeming critical of Leona Schauble and Rich Lehrer, the researchers who made these videos, and who appear in them. Let me state at the outset that I think they have been extremely generous, even brave, to permit us to view their video-recordings. I apologize in advance for anything I say that sounds unduly critical, and I'm open to correction.

As Wertsch and Kazak interpret the activity in Group 3, which as the video begins has been joined by Leona, she – the adult, the expert – has a considerable responsibility for the learning that occurs. First, she "was able to. . . impose some order on the task"; "to rein in the students' seemingly aimless wandering." She did this in an "attempt to push their thinking to a higher level" (p. 160). She "explicitly and directly proposed" (p. 161) the kind of graph that is needed, and how the graph paper should be used; and then she "moved on ahead with more concrete suggestions" (p. 161) that lead the students to at least some degree of success.

On the other hand, Wertsch and Kazak see the *students* in Group 3 in a much less positive light. At first these students "did not really know what they were doing" (p. 160). They showed "confusion, or misunderstanding of the proper use of the graph paper" (p. 161). Initially they were only "using it at a primitive level" (p. 160). However, they responded with "insight" (p. 162) to the adult's explicit proposal that they construct a frequency chart. And at the end they "are clearly much closer to an expert's perspective than they had been earlier in the session" (p. 162).

This is obviously a very quick sketch of Wertsch and Kazak's analysis of the videotaped episode for this group, omitting many details. And limitations of space prevent me from offering in any detail my own analysis of this same episode. I can only point out a few highlights that illustrate some important points of disagreement.

First, I'm struck by the degree to which key decisions in the task are made by the adult. As Wertsch and Kazak noted, she defines the type of chart to be drawn, proposing columns in which an X would be made for every measure that falls between two numbers:

Excerpt 4 [0:24:14–0:24:18]

0:24:14 LS: Well what if we had (.) a col:umn, (0.5) sa::y (0.5) >let me think about this for a ⌈minute< (.) two hund'rd- (.) you have two hundred and two- (and) thirty, two hundred twenty-five num::bers↑ >two fifty<
0:24:18 Edith: ⌊((*Rolls her eyes*))

She chooses the units of scale for the main axis of this chart, wondering aloud whether the appropriate unit (bin size) is 20, or 10:

Excerpt 4 [0:25:28–0:25:40]

0:25:28 Edith: =and then we could do ninety blahblah
0:25:30 LS: Or maybe we could do it with twenties I don't know lets count, twenty forty sixty eighty one (.) ten- twenty forty sixty eighty. That would be (.) maybe we could even do it by tens↑.

It is the adult who counts along the axis first in 20s, then in 10s, and announces that 10 will work. And when the students hesitate it is she who writes the labels along this axis.

The adult, the expert, is certainly trying to lead, but are the children, the novices, following her? One might argue that they follow too well. The children seem to be trying to do two things at once: they are trying to negotiate the assignment while simultaneously following the lead of the adult. The two should be compatible, but there are problems. For instance when Leona proposes "Let's see how many squares we have" [0:22:20] the students take this as an invitation to compute the area of the graph paper. When they do this Leona appears puzzled [0:23:08]. When Leona proposes that they draw a histogram Jasmine responds, "Hha ha I don't know what you're talking about actually" [0:24:45]. Edith, in contrast, produces an avowal of understanding, exclaiming, "Oh!," which in an early draft of their chapter Wertsch and Kazak took as suggestive of a "new insight. . . as to how the graph paper could be used. . . to get at the issues of central tendency and variation." But in fact central tendency and variation haven't been mentioned in regard to this new kind of chart. Leona has suggested only that their goal is to "get a sense of the different sizes of fast plants." And when Erica is called upon to actually move the work forward it becomes clear that she doesn't know how to construct the histogram. As she is starting to label the "bins," she stops and exclaims, "This is confusing. How are we gonna dra- (.) how are we gonna draw this out?" [0:28:37]. Jasmine tries next, but ends up asking "What are we doing?" [0:28:52]. It is at this point that Leona takes the graph paper from them and writes the labels herself. The children watch, and

Fig. 10.1 Edith: “I really don’t understand this.” (Excerpt 4)

Edith says, at first quite loudly, “I *really*: don’t’ understand this” [0:29:00]. As she’s saying this she covers her mouth, as though to hide her confusion (Fig. 10.1).

In general the students don’t challenge the adult to explain her suggestions. They offer tokens of agreement that seem to indicate politeness rather than comprehension. On the other hand, these students are not without their own proposals for organizing the data. For example, when Leona asks them to “stop and think about what it is we want to know,” Jasmine offers a suggestion (cf. Fig. 10.2):

Fig. 10.2 Jasmine offers a suggestion (Excerpt 4)

Excerpt 4 [0:24:01–0:24:14]

```
0:24:01 Jasmine:   We can like um add these together because you
                   know >one two three four five< we could jam
                   together you know? And then we could use just
                   the even numbers or the odd numbers cuz one is
                   an odd number and then we could just show the
                   odd numbers maybe
```

In summary, there are several ways in which my interpretation of Group 3's activity differs from the interpretation offered by Wertsch and Kazak. First, where Wertsch and Kazak focus on the children's seeming initial lack of understanding of how to use the graph paper, I would argue that there is a mutual lack of understanding between children and adult. The children don't seem to understand the adult's proposals, despite their nods and polite exclamations. But it's equally true that the adult doesn't understand the children's proposals. Second, it is true that the adult leads, but she does so in a manner that is, to borrow a term from Greeno, "authoritative" (p. 58). The children do not follow her if by "following" we mean not just agreeing to do what the adult proposes but also demonstrating their comprehension of the proposal. For, although Wertsch and Kazak state that the children move closer to the adult's perspective on how to appropriately use the graph paper, there is not much evidence for such a movement. But, as I've said, the children have their own proposals for organizing the data, which we don't yet really understand. We see here something I will explore in more detail later: that the students prefer a specific kind of representation of the data.

Group 3: Novices Lost Without an Expert?

The second group that Wertsch and Kazak examine operates without adult assistance, and thus offers an interesting contrast with Group 3. The video (Excerpt 3) omits the first 5 min of this group's work and so we don't know how they initially approached the task. As we join them they seem to be explaining their work to an adult who is not visible on the screen. They seem to say they'll be constructing a "line chart" which will make it easier to see the average. The adult soon leaves and they continue to work without expert assistance.

Knowing Wertsch and Kazak's position that schooling is domestication and that learning requires expert guidance, one would anticipate that they would expect that a group of novices working alone would not be able to accomplish much. Indeed, Wertsch and Kazak's interpretation of Group 2's activity is that they achieve little until an adult – Rich – joins them and redirects their activity. They describe the students as "far from fully understanding what 'organizing the data' means" (p. 163). In an early draft of their chapter they suggest that "the questions posed by RL seem to have initiated a new level of intersubjectivity between the students and the adult." The final version is more ambiguous about the origin of change: they write "a new level of intersubjectivity seems to emerge" (p. 163).

I don't believe the first interpretation survives close scrutiny of the video. Group 2 has a prolonged, at times heated, but essentially productive debate over how to construct their chart. Rather than indicating a lack of understanding, their interaction evinces a progressive resolution of ambiguities inherent in the task, conducted in a manner that is basically respectful, though not entirely rational, insofar as allegiance to shifting alliances within the group appears to explain some of the choices that are made. To understand the interaction it is key to focus on the way the graph paper begins as figure in the children's activity but ends by being a ground. That's to say, at the start of the session the graph paper is the object that is discussed, while by the end it is a taken-for-granted background or field upon which lies the object of joint attention. This is what I will later call an "ontological construction."

Discussion begins with the issue of the placement of the chart on the paper: how the "axes" should be oriented in terms of the "sides" of the paper. The students debate the capacity of each side: is it long enough to construct an axis along which they can fit the data values that they need to include? For example, Anneke offers, "Could you put sixty-three: things across here?" [Excerpt 3, 0:11:41]. Jewel counts in fives, then Wally, recommending "Look at this" [0:11:57] counts in tens, the two of them thereby offering competing public demonstrations of the capacity of the short side of the paper. April points out that they will need two axes "anyway" [0:12:37] thus postponing the selection of which side will be the X-axis and which the Y. Wally concurs – "Then we can do it (0.3) *any*way" [0:12:51].

The disagreement over X and Y axes thus circumvented by postponing the decision – "just draw it *fir*s:t" [0:12:54] – construction begins with pencil and ruler, Jewel drawing the long axis, Anneke the short one. While Jewel completes this, Anneke and April collate the data, in a spontaneous division of labor that arises from the needs of the task as they now understand it.

Once Jewel has finished drawing and Anneke has returned from examining the data display, conversation returns to the orientation of the axes:

Excerpt 3 [0:14:06–0:14:15]

```
0:14:06 April:     Okay, what way do we want to do it?
0:14:08 Wally:     This::.
0:14:09 Anneke:    Jewel, you can't do it this way.
0:14:11 Jewel:     >What?<
0:14:11 Anneke:    >Don't do it this way< cuz then >>you can have
                   more room to write it.<<
```

In the course of this discussion disagreement arises about the seemingly straightforward issue of which is the "top" and which the "bottom" axis. Which is "left" and which is "right"?

Excerpt 3 [0:14:35–0:14:49]

```
0:14:35 Jewel:     Which is the left?
0:14:37 Jewel:     This is the top, this is the bottom what dya'
                   mean the left? The left would be (.) over
                   here.
0:14:42 Anneke:    The left would be right here. No right here.
0:14:43 Jewel:     No it woul⌈dn't
0:14:43 April:               ⌊Okay you guys, we wanna do this.
0:14:45 Jewel:     You're looking at it from this (0.3) point of
                   view, okay?
0:14:48 Anneke:    No we aren't! We're ⌈doing it this way.
```

The students stumble across the importance of "point of view." Terms like "top" and "bottom," "left" and "right" are of course indexicals – and each of the children, arranged around the table, uses them to refer to a different aspect of the paper. The graph paper is a material artifact and as such, each child engages with it primarily in an embodied manner: touching it, moving it, gesturing to it. In this regard it fits within each child's body-centric frame of reference: perceived as "in front," as having "a left-hand side," "a right-hand side," and so on. This frame of reference defines aspects that seem to be those of the object itself: a "top," for example, and a "bottom," and so on. But the body-centered frames of the children do not, of course, correspond directly, because the children are facing in different directions. "Top" and "bottom" are not properties of the object itself, they are actually defined with reference to the point of view of the agent: what is Jewel's "left" is Anneke's "right." The children recognize this source of confusion without outside help, and agree to adopt a canonical point of view. Jewel, at the suggestion of Anneke and Wally, actually steps around the table to literally look from Wally's point of view [0:17:08]. The four begin to use language that is less indexical, or whose indexicality is to a context that is shared, not body-centric – talk of "the long side" and "the short side," for example.

The topic of talk now shifts from the paper to the chart and its properties. Discussion moves from the issue of how X and Y coordinates are conventionally arranged, and from confusion about which is left and right and which point of view they're looking from, to the substantive issue of which axis will work as an X or Y axis. Indexicals now no longer refer to the sides of the paper, but to the orientation of the chart's axes. The properties of the paper are now pretty much clear and can be taken for granted, but the properties of the graph being drawn on it are not yet agreed upon. Each child projects a possible construction, and apparent consensus keeps dissolving. As yet the distribution that is to be graphed is talked about only in very general terms, such as the number of data values and their range.

Choice of which axis is "the top" and which "the bottom" depends on how much data can be "fit" into each, and appreciation of this issue leads the group to debate the capacity of the axes again. For example, Jewel questions the proposal to fit 200 data values along the long axis: "Can you make two hundred some right here?" [0:15:00]. But the capacity of each axis depends in turn on the choice of units of scale. April proposes that with a bin size of 5 the values will all fit nicely on the short axis: "We can do fives" [0:15:18]. The starting and ending values are important too, and the group check the original data display to see what the largest and smallest data values are.

Excerpt 3 [0:15:24–0:15:44]

```
0:15:24 Wally:              ⌊(     ) go up to two hundred (     )
0:15:26 Jewel:      YES IT DOES it goes above two hundred and
                    twelve.
        Jewel:      No (.) wait
0:15:31 April:      No, hundred ten, two hundred thirty, two
                    hundred fifty (up to here). Okay you guys?
```

As is evident in this exchange, the children challenge each other freely throughout these conversations, in a manner that at times gets heated but remains respectful, and which allows the articulation of their differences.

The choice of X and Y axes still undecided, discussion now turns to the details of the distribution to be constructed: the range in the data values, where a data value gets placed, what is written to identify it, and where this is written. And this leads to the issue of what the graph is "saying" or "telling":

Excerpt 3 [0:18:07–0:18:22]

0:18:07	Wally:	=Okay Anneke, Anneke, Anneke Okay. Fifty-three numbers? Okay. that would be telling them with the graph. That's why were making the graph.
0:18:15	Jewel:	We're saying it's Day Nineteen what (.) how is it going?
0:18:19	Anneke:	↑I see::.
0:18:20	April:	Yah but you haf to label it.

The children make easy use of notions of lowest and highest, make implicit use of ranges, and count skillfully in units of 5 and 10. They quickly reach agreement that the unit on each axis cannot be unity, and when they debate and disagree on the choice of unit they appeal to notions of practicality (the size of the paper), and accuracy [0:16:26]. They seem to be searching for the most efficient representation: to make optimal use of the paper by choice of axes, minimal value, etc. This task is challenging, but for important reasons, since alternative strategies must be voiced, explored, debated, rejected, retrieved, and eventually agreed on. Disagreement over the character of the distribution induces appeal to the aim of their activity. Finally it seems that a consensus is reached, and the children recognize, mark and celebrate this, even though Anneke challenges Jewel for being inconsistent in her line of reasoning about labeling the chart:

Excerpt 3 [0:18:27–0:18:44]

0:18:27	Anneke:	>WAIT a minute< (0.7) (then the)
0:18:30	April:	Oh:::::!
0:18:31	Wally:	Okay finally! Hh huh.
0:18:33	April:	Well you could you didn't you didn't you weren't trying to make that point Jewel.
0:18:20	Jewel:	Yes I was:.
0:18:39	Wally:	No::: you weren't.
0:18:40	Jewel:	Yes I was.
0:18:41	(Jewel):	No:::::.
0:18:42	Wally:	Sixty-three numbers across there.
0:18:44	Jewel:	Okay poop.

In sum, the children in Group 2, although they have no adult leading them, are able to agree on the type of graph they will construct (it is presented in Excerpt 12); arrange the orientation of X and Y axes; place start and end points on each axis; and determine the appropriate unit of scale. In other words, this group of "novices" is able "without intervention from a teacher" to make the same decisions that the "expert" adult made for the first group. Their interaction shows, I would argue, productive engagement in the task, an ability to work successfully together, and clear progress in their understanding of the task and of one another. They work very well together, despite the absence of adult expertise.

However, Group 2 does not make a histogram! And when adult authority arrives, in the shape of Rich, they are pressed to justify this. "Did anyone say tha it hada be a *line* graph?" Rich asks [Excerpt 5, 0:41:22]. Should we judge Group 2 a failure because they chose to construct the wrong type of graph until an adult expert set them straight? This question is an important one, for evaluation of classroom practice is the topic that has drawn us together. If we accept the way that Wertsch and Kazak evaluated the students in the first group we would have to say yes, the second group failed too. As I have noted, Wertsch and Kazak write of the first group of students that they showed "a low level of sophistication"; that had "inappropriate," even "primitive" understanding, and "did not know how to use it [the graph paper] as an expert would." They failed to grasp "how it [the graph paper] could help organize their activity in a socioculturally appropriate way" (p. 160). Of Group 2 Wertsch and Kazak write that before the adult arrives, "they are far from fully understanding what 'organizing the data' means" (p. 163). Even after discussion with the adult, "they were still struggling with the question of what it means to organize the data from an expert point of view" (p. 163).

If by this Wertsch and Kazak mean that the students were struggling to understand the adult perspective I would agree with them. But what Wertsch and Kazak evidently mean is that the students hadn't yet grasped the correct way to organize the data, and with this interpretation – and evaluation – I must disagree. The criterion for Wertsch and Kazak's evaluation of both groups' performance is "appropriate use" of the graph paper. But can we be sure that we know what "appropriate use" is? We have arrived at the third claim in Wertsch and Kazak's paper, that the graph paper is "a robust material sign vehicle" which fosters interaction between adult and children.

Appropriate Use of the Artifact?

Early in the lesson the teacher wrote two questions on the board: "What is the typical height?" and "How spread out are the heights?" [Excerpt 1, 0:01:14–0:02:14]. It would seem natural to interpret the first as a question about the central tendency of the distribution of measurements. Wertsch and Kazak write that "In this context, the term 'typical' . . . has a special meaning . . . it points to a measure of the central tendency of a data set" (p. 159). But can we be sure what "typical" suggests to the children? One might see the question as deliberately vague, leaving it up to the children to explore what typical might refer to. Even if typical does point to central tendency, this could still be mean, mode, or median. We learn from the second video-recording that these, and the differences among them, are discussed the next day. There are important differences among these three measures. One I wish to emphasize is that while mean and median are properties only of the distribution of scores, mode will also be a property of individual plants. There will, by definition, be several plants that have the modal value, while there may be no plants whose height is equal to the mean or the median. The importance of this will become clear later when I argue that the children prefer a form of representation that maintains the identity of their individual plants.

If central tendency can be a matter of mode, as well as mean or median, is a histogram the only "appropriate" way to assess "the typical height"? We learn from the videos themselves that it is not: on the 2nd day Wally presents to the class a chart drawn with Cindy and others which, he argues convincingly, displays the mode of the distribution while retaining all the individual scores. I can see, then, no *a priori* reason for saying that drawing a histogram is the only appropriate way to use the graph paper to answer the question "What is the typical height?"

Secondly, when we examine the teacher's directions to the students we see that he introduces, presumably unintentionally, a disconnection between "organizing the data" and answering the two questions:

Excerpt 1 [0:04:48–0:05:08]

```
0:04:48 teacher:  First you're gonna organize your data
0:04:50 Tyler:    Yeah and then we're gonna
0:04:51 teacher:  And then we'll probably ⌈discuss how we're
                  going to do this::
0:04:53 teacher:                          ⌊((pointing with piece
                  of chalk in left hand toward the two questions
                  written on the board))
0:04:54 teacher:  Ahm: and so you can be thinkin' about that as
                  you as you're starting to organize your data,
                  (1.0) ahm:: (0.4) well we'll discuss how to
                  answer these questions. How we might go about
                  that.
```

This formulation appears to indicate that the students should "first" organize the data "in some way" (no suggestion here that there is only one way) and only subsequently – "then" – think about the questions. The advice that they "can" think about how to answer the questions as they organize the data doesn't indicate that they should ensure that their organization be designed to facilitate their answers. The indefinite postponing of discussion of "how" to answer the questions also suggests that the organization of the data is a preliminary task. Overall, the teacher's instructions give no suggestion that there is a single "appropriate" use of the graph paper in this classroom activity.

Third, when the graph paper is handed out it is described by the teacher as being "your final copy" which "you will be putting up in front of everyone":

Excerpt 1 [0:05:10–0:05:34]

0:05:10	teacher:	⌈⌈Rene want to pass those out? one to each group.
0:05:10	teacher:	⌊⌊((*lifting a stack of sheets of graph paper from desk*))
0:05:14	teacher:	This your final copy (.) sheets that you will be putting up in front of everyone so:
0:05:34	teacher:	Here's your final copy, here's your pen for your final copy.

Like Clancey (Chapters 15 and 20, this volume) I am struck by the unfortunate consequences of this: the students are discouraged from writing on the graph paper until they have solved the problem. To mark it incorrectly – with a pen, which cannot be erased – is to risk public embarrassment.

The teacher has placed emphasis on product rather than process, on finality rather than open-endedness, on whole-class display rather than group work, on public evaluation rather than safe exploration. (Not to mention the fact that the students have cameras and microphones around them, and that their products are both filmed and photographed!) Consequences of this are soon apparent: students tell one another not to wrinkle the paper; careful erasing is frequent; and we see students gesturing at the paper and talking about what they might do when drawing a few clear but exploratory lines would be more helpful. Even as a material cultural artifact the graph paper is laden with the injunctions of authority and the accountability of public display. Understanding these aspects of the graph paper's role as mediating artifact is crucially important. The students aren't engaged solely in a cognitive task, they are motivated by desire for recognition by teacher, peers, researchers, and whoever they think will be watching the video-recordings (cf. Packer & Goicheia, 2001).

There is a poignant illustration of this when Rich is talking with Group 5. He encourages them to start writing on the graph paper, but Rachel objects that they are "not sure." Rich presses them to "go ahead," and she makes a pleading and conspiratorial gesture to him, saying, "It's our final copy!":

Excerpt 6 [0:49:42–0:49:50]

0:49:42	Rene:	⌊Well we're not sure if we are gonna do this. =
0:49:43	RL:	= Well go- go ahead↑ write it. (0.9) jus let's see what you have.
0:49:47	Rene:	⌈It's our final copy.

Fig. 10.3 Rene: "It's our final copy." (Excerpt 6)

Rachel's facial expression, her gesture and her tone of voice convey the appeal that Rich should understand their delicate position and not insensitively push them to mess up their paper (Fig. 10.3).

So while I would agree with Wertsch and Kazak that the graph paper does mediate interaction between adult and student – and also interaction among students – I cannot agree that it is straightforwardly a "mediator between different levels of understanding" (p. 164), as they put it. The graph paper's mediation is defined by the roles and responsibilities of the classroom. The teacher's introduction of it as "final copy" defines its social significance as a public display of the group's work, as an artifact for public evaluation and recognition. It is not a resource for the students to work on and explore with. In addition, the teacher has posed the task in a way that disconnects organizing the data from answering the questions. The questions about what is "typical" have been, perhaps deliberately, phrased in an open-ended way. All these considerations, apparent when we undertake to examine carefully the complex ways in which the graph paper actually moves within classroom activity, undermine any effort to claim that the single "appropriate" use of the graph paper is to draw a histogram.

Preferred Representations

However, there certainly is in this classroom what James Greeno calls a "preferred representation" (p. 56). The adults clearly prefer that the students draw a histogram. To be specific, they indicate in various ways and numerous times a preference that the students construct a bar chart showing the frequency distribution of the 63 data points, with its Y-axis labeled with possible heights in the range and its X-axis "binned." Furthermore, as we have seen, they are authoritative about this. In his discussion of Rich Lehrer's interaction with the "novices" of Group 2 Greeno observes that at least one of these students already prefers a “bar graph” in which “it doesn’t matter what the names. . . of the plants are” (April’s words: [Excerpt 5, 0:40:20]) and that “the resolution appears to have been more of a concession and less of resolving alternative opinions” (p. 58). Greeno concludes that “the authoritative position that Lehrer held in the participation structure seems needed [from the analyst’s perspective] to account for the group’s conclusion to omit the plant numbers from its representation” (p. 59). Greeno’s observations further challenge the interpretation that interaction with the adult expert leads the novice students to what Wertsch and Kazak term, “a new level of intersubjectivity” (p. 163).

A number of the participants at the conference noted that many of the children clearly prefer not to relinquish data about the individual plants whose height they have measured. In several groups we observe a clear tendency, albeit initially unquestioned, unexamined and hence unarticulated, to include the plant numbers. This tendency finds satisfaction in a variety of different constructions on the graph paper, but not in a histogram, since the binning of data means discarding all indication of the identity of individual plants. There are in fact *two* preferred representations in this activity: one preferred by the adults, another preferred by the students, and these two preferences are at odds.

Why do the students have a preference? Why are they unwilling to forget plant identity? We can only speculate that it is because this would mean forgetting also the identity of the student who first grew and then measured each plant. Garrison (Chapter 18) notes that with this “decontextualization” of the graph “whatever motivational interest may have accrued to the actual process of growing plants and measuring their maturation has departed the pedagogical scene” and as a result “the students seem unable to retain continuity between the two inquiries” (p. 311). If Garrison is correct, as I believe he is, the children’s preference shows not cognitive primitivism but their keen motivation and personal involvement in the classroom task.

Sometimes the students strongly defend their preference to the adults who question it. I’ve already mentioned the occasion when Rich speaks with Group 5, and here as with Group 2 the discussion centers around the fact that they have chosen not a frequency chart but a line graph in which plant identity is retained. Janet is the chief spokesperson for the group at this point, and she makes a strong effort to justify to Rich what the group is doing, which I will quote at length:

Excerpt 6 [0:51:45–0:51:22]

```
0:51:45 Janet:     = >Do you-< do you understand why we need the
                   heights?
0:51:48 RL:        I understand the hei⌈ght.
0:51:49 Malcolm:                       ⌊Hehehehe.
0:51:49 Rene:      Yeah but ⌈(.) we had number twelve. Explain
                   number twelve.
0:51:49 Janet:             ⌊(But this::,)
0:51:52 Malcolm:   Yeah hehehehehe ⌈(                    )
```

0:51:52 Janet: ⌊°Because° (.) because (it's numbers and it's just like) ⌈okay if you put them in alphabetical or:der,
⌈well what's number twel::ve?
0:51:55 RL: ⌊Okay?
0:51:58 RL: ⌊Well what's, (.) Janet? Janet? Calm down. ((*raising hand*))
0:52:02 RL: So (.) that I understand.
RL: Let's cgh- think about this >just for a second here though< what (.) let's think about the other ones if we (did) (.) another kind of graph
0:52:12 Janet: Well we weren't =
0:52:12 RL: = Wait for, Janet? ((*raising his hand*)) >Wait a minute.< What other people said (.) was that (.) they were going to do ah do something they called a histogram.
0:52:21 Rene: A what?

There's every indication here that the children are very aware that the adults do not *share* their preference. But their conduct suggests that their interpretation of this is that the adults fail to *understand* their preference. They persist in trying to explain, so vehemently that, on this occasion at least, the adult raises his hand to silence then. If there is no reasoned debate this is not because the students are unable or unwilling to engage in it. Here too, I would propose, we see concession – albeit reluctant – by the children to the adult's authority rather than a reasoned debate in which the adult's preference is accepted because of rationally compelling arguments (Fig. 10.4).

Of course Rich isn't a bully. To him, the preference for a binned histogram is rationally compelling. Continuing to argue for the histogram, he draws an analogy to a previous rocket-launching activity, and now it is Rachel who offers an explanation of their preference:

Fig. 10.4 RL raising his hand (Excerpt 6)

Excerpt 6 [0:53:01–0:53:32]

0:53:01 RL: Well lemme ask you lemme me ask this (0.9) suppose the (.) data were not about plant heights, but they were how high the rocket went?
0:53:13 Janet: ⌈⌈You'd still use it (for this) to show the different heights the different rockets <u>went</u>, ⌈up and up.
0:53:13 Janet: ⌊⌊((*tapping pencil in an ascending curve across graph*))
0:53:17 RL: ⌊Okay!
0:53:19 Janet: ⌈⌈( )
0:53:19 Rene: ⌊⌊And it um would be the first rocket? tha (.) first one because it's important to see (.) which one it was because (.) ahm (.) which plan- or which:: in this rocket it was because ⌈(0.7) ahm ( )
0:53:31 RL: ⌊Uh huh.
0:53:32 RL: Well the rockets we all sent up at the same time right? or almost?

Once again there seems to be mutual misunderstanding. The children are strongly defending their preference to include individual data, for either plants or rockets, but the adult does not understand their reasoning. Equally, they evidently don't see the logic of his position. In the absence of mutual understanding the definition of which construction is the "appropriate" one becomes a matter of adult status and power rather than reasoned discussion.

I have argued that we see in these video-recordings conflicts and potential contradictions between the active construction by children and adult authority in the classroom, and that these conflicts have important implications for a sociocultural theory of learning and schooling. Constructivists often expect the child to spontaneously reinvent adult mathematics, because the believe that the latter is logically compelling. Wertsch and Kazak don't take this stand: they state that "no amount of exploration on the part of novice students will yield the discovery of things like graph paper and histograms [because] [t]hese are historically evolved cultural tools" (p. 165). But what they offer instead is a conception of learning and schooling where adults' definitions of "appropriate" use of classroom artifacts are to be accepted without question by children. Learning as domestication. I think Wertsch and Kazak overstate the case – one could imagine that creative children could inscribe a grid on paper (cf. diSessa, Hammer, Sherin, & Kolpakowski, 1991) – but certainly the practices and artifacts of adult professional mathematics may not be spontaneously reinvented by children. These practices, "historically evolved," are products of numerous conventional choices. In the specific case we are considering here, the use of a histogram to represent a distribution of scores is one option among many, and this is the source of something importantly problematic in the classroom. The children are intent on finding a use for the graph paper – and constructing a new kind of object – that the adults apparently did not anticipate and which they do not consider adequate. When we look carefully at the video we discover that the adults' preferred use is not justified in logical terms, and instead they use their authority to have the children's construction conform to their preferred use. There is this much truth the Wertsch and Kazak's proposal that teaching is – or can be – "domestication." But this is not what Rich and Leona intended. To avoid unnecessary domestication the experts need to recognize that understanding in mathematics, as in any area of human activity, "happens within the boundaries of what is contingent" (Felicilda, 2001). The issues here are not unique to math: in all arenas of learning we must grapple with the problem, both ethical and epistemological, that while we might wish children to do things "our way," our way is generally not the only way, the logical way, or even the best way. "Where two principles really do meet which cannot be reconciled with one another, then each man declares the other a fool and heretic.... At the end of reasons comes *persuasion*. (Think what happens when missionaries convert natives)" (Wittgenstein, 1969, p. 81, emphasis in original).

Learning as Sociocultural Ontological Construction

Let me summarize the points I've been making. First, some students in the class make progress in the activity without adult assistance, indicating that adult guidance is not a necessary component, and in this respect I must disagree with Wertsch and Kazak's emphasis on expert-novice interaction as the basis of schooling. I've also argued that it proves difficult to sustain the claim that there was a single "appropriate" way for the students to use the graph paper in this task, given the ambiguity of "typical" plant, the disconnection between organizing the data and answering the question, and the status of the graph paper as "final copy." Wertsch and Kazak elevate to normative status the preference that the adults in the classroom had for one specific representation. This representation was indeed what most of the groups ended up producing, however the students themselves had, at least initially, a different preferred representation, one that preserved the identity of the individual plants. In insisting that the graph paper had one appropriate use, Wertsch and Kazak gloss over and hence legitimate the ways in which the adults' preferred representation "trumps" that preferred by the students. Wertsch and Kazak thus legitimate an element of the Fast Plants pedagogy which involved domestication rather than argumentation.

Wertsch and Kazak seek to contribute to the debate over differences and merits of sociocultural and constructivist theories of learning and development (cf. Packer & Goicoechea, 2000). But their "socioculturally situated constructivism" still focuses only on the construction of knowledge, neglecting the ways both knowers and known are also constructed, and as they conceive of it, knowledge-construction is a solely conservative process, ascending to – and reproducing – the levels of adult-defined expertise. Goicoechea and I have argued that what is needed is not a "synthesis" but a "reconciliation," one that involves seeing that constructivism is an "as if" (Sfard, 1998, p. 12) that presumes that we are cognizing individuals but does not examine how we may become such an kind of person. Socioculturalism, properly formulated, does tell a complete story, one of "a practical process of construction where people shape the social world, and in doing so are themselves transformed" (Packer & Goicoechea, 2000, p. 234). Such a formulation requires a non-dualistic ontology, which we have proposed has six components: (1) the person is constructed, (2) in a social context, (3) formed through practical activity, (4) formed in relationships of recognition and desire, (5) that can split the person, (6) motivating the search for identity. School is a place where children become new kinds of person (Packer, 2001). As Dewey noted, "a criterion for educational criticism and construction implies a particular social ideal" (1916/1966, p. 99). One such ideal could be that children merely master the expertise of their elders and betters, but such an ideal pays little attention to either the rapid changes in the technology and economy of contemporary society which render adult expertise obsolete, or the existence in adult practices of inequities and inadequacies which we would wish our children to overcome. Most importantly, no single social ideal and consequent criteria for schooling should be enshrined in theory, when the choice of ideal should emerge from a political process of debate and reasoned disagreement.

We witness the construction of objects in the children's treatment of the graph paper. Wertsch and Kazak view it as an unambiguous artifact with well-defined use and meaning, but if we look closely we see the artifact being transformed. It begins as a sheet of *paper*, marked with what could variously be interpreted as cells, or a grid, or a lattice. This paper has properties which the children discuss and debate: it has long and short sides, these have length, numbers of cells, etc. But the paper quickly becomes the ground for the construction of a *graph*, which has new and different properties: axes, with length and orientation, points with position relative to the axes, labels of various kinds. And this in turn becomes ground for construction of a *distribution*, which has range, central tendency, and so on. When the children display their work on Day 27 of the unit, it is the distributions they are sharing, not the graph paper. The paper has become an invisible backdrop to this new construction.

Which of these is "the artifact" – paper, graph, or distribution? The answer has to be that there is no single artifact; what we witness is the transformation, over time and through practical social activity, of an object of knowledge. Even a description of this object, let alone its evaluation, requires an understanding of the context in which it moves and the actions performed on it.

I have just described this changing object from a cognitive angle, but it can be viewed also from a social angle. It begins as "final copy," already caught up in familiar routines of whole-class display and teacher evaluation. It becomes an object of joint yet distributed attention, as the children seated around it must recognize that their indexical references (to "top," "bottom," "here," "there") require a common frame of reference if they are to understand one another and successfully work together. When adults arrive it becomes something to be described, explained and justified. The following day it becomes an exhibit for public display and comparison. Everyone – teacher, small groups, adults, whole class – plays a part in the construction and reconstruction of this object. And this is not the end of its story:

now a completely different audience of academics recontextualizes it and interprets it afresh. It was anticipation of such an analysis, presumably, that motivated the video-recording of the class, and perhaps the design of the instructional task in the first place, so a complete description of "the artifact" would follow it out of the classroom in Wisconsin to a conference room in Illinois and then onto these printed pages, where it has become an element in a wider social and intellectual praxis.

In short, then, knowledge is not all that is constructed in a classroom. The objects of knowledge are constructed and reconstructed in complex trajectories of collective activity. The knowing subjects – the "students" – are constructed too (although tracing the transformations of the children in these short segments of video is much harder than tracing transformations of the objects). Learning is not solely a matter of change in subjective knowledge structures, it is about changes in the world: artifacts in the classroom are transformed, becoming mathematical, physical and biological objects.

It will be clear that I disagree with Wertsch and Kazak's suggestion that "a great deal of the negotiation of meaning and intersubjectivity involved in our example looks like the kind of processes that are of interest to constructivists" (p. 165). I have pointed out that constructivists are interested in the construction of knowledge, while what we can see in this example, and what socioculturalism can and should concern itself with, is the construction of knowing subjects and known objects. While Wertsch and Kazak see a need for a synthesis to which "constructivism has a great deal to offer" I have argued for a reconciliation in which the construction of knowledge is subordinate to a more profound construction or constitution of known objects and knowing subjects.

In addition, while I do not consider myself an expert in Vygotsky, I have doubts when Wertsch and Kazak write that constructivism "indeed addresses a weak point in Vygotskian theory" (p. 165). Vygotsky offers us a powerful illustration of an approach to psychology which, based as it is on Marx and Hegel, places process at center stage, deals with phenomena holistically rather than by dissecting them into variables or elements, shows how the appropriate choice of unit can show the whole in each of its parts, shows the importance of understanding the dialectic between nature and culture, and places all this in service of important social goals. Constructivism doesn't seem to me to have much to add to this.

But Vygotsky's theory cannot be lifted out of its time and place without damage. His aim was to articulate a scientific psychology that was of immediate practical and political value, satisfying the needs of the newborn Soviet Union. "Vygotsky declared that the motto of the new psychology was 'practice and philosophy.' That statement was not a mere declaration, it had a personal significance to him. The unending shuttle-like movement of Vygotsky's thought between practice and philosophy determined his highest achievements" (Yaroshevsky, 1989, p. 16–17), as he and his colleagues were "becoming active builders of socialist culture" (op. cit., p. 71). He sought to forge the tools needed in a new kind of society. "Soviet society demonstrated its potential for transforming the individual's spiritual world on new, humanistic principles. The reality surrounding Vygotsky, the people and their activities were changing right before his eyes. Historical changes were taking place both in being and in consciousness. Feeling the rapid beating of the pulse of the times, Vygotsky absorbed the principle of historicism and social determination of behavior not only as a philosophical imperative but also as a guiding principle in the transformation of man" (op. cit., p. 104). Vygotsky intended that his scientific psychology would provide the tools needed to bring to fruition the deliberate cultural transformation of human nature (cf. Packer, 2008).

Vygotsky's work shows the mark of its times in other ways. His remarks that novices must be led by experts shows the vanguardism of post-revolutionary Russia, when Lenin (1902/1971, p. 37) could write that revolutionary consciousness could never arise spontaneously in the working class, "It could only be brought to them from without" by "the revolutionary socialist intelligentsia." Vygotsky took Marx's *Capital* as his model of a dialectical science; Marx's earlier, "humanistic" writings, which contained a more subtle account of false consciousness and alienation, were unavailable.

Today in the U.S. of the early twenty-first century we are not so quick to dismiss the ability of the disadvantaged to grasp the inequity of their circumstances, or to judge that "an illiterate person stands outside politics" (Lenin, cited in Davydov, 1988, p. 8). We are less likely to reject attempts at reform and opt for radical revolutionary change. We know how the Soviet vanguard became an ossified party bureaucracy at the center of a totalitarian state. Certainly we don't think of ourselves as having a perfect society within reach. We need, then, to use Vygotsky's writings as a guide as we grapple with our own problems, not as a solution to them. In broad terms our aims will be the same: to comprehend "changes… in both being and consciousness" and to foster these in a practice both social and political. But our work must be tailored to and based on an understanding of our historical and cultural circumstances – of post-industrial capitalism, economic and cultural globalization, and religious polarization.

Sociocultural theory is an important step forward from the notion that development is oriented by a single, overarching and universal rationality – a rationality which, oddly, was most accessible to white, male, middle-class westerners. But we must avoid falling into an epistemological and ethical absolutism in which "mastery" is the sole criterion of "expertise," and those who are seemingly deficient must be "tamed." Stripped of its "scientific" legitimation, this absolutism shows itself to be a cultural relativism. (Bernstein [1983] has diagnosed the "Cartesian anxiety" that lies behind both dogmatic objectivism and anything-goes relativism.) Instead, an approach that is sensitive to cultures must be pluralistic, neither universalistic nor relativistic, granting the qualitative differences between child and adult, and also granting that different cultures have valid, though distinct, rationalities. Like contact between adult and child, contact between cultures, and the move from one to another, require dialogue, mutual understanding and bridge-building, not domestication and taming.

Finally, some brief remarks about our general project here, the evaluation of classroom practice. It's become apparent how important it is to study an activity in its entirety: lack of video of how these groups started and finished their activity limits our ability to understand what they've done, and why. It's equally important to seek norms internal to the activity, and not impose norms from outside. The local interaction, in the small groups, must be understood and evaluated in the context of the classroom as a whole – we've seen that norms of public accountability influence what the students do and don't do. In particular, we need to know the teacher's instructional goals – what was this teacher trying to achieve with this activity? – but we can't take these for granted: we must evaluate them for internal consistency, for transparency, and for the degree to which they are in accord with what schooling has been judged to be by the school as a whole, by the school district and by the community.

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Chapter 11
Developing Fluency versus Conceptual Change

Bruce Sherin

Introduction

In their contribution to this volume, Wertsch and Kazak turn to a theoretical tradition they trace to Vygotsky, as well as to the lesser-known Gustavovich Shpet. They argue that, viewed from the perspective of Vygotsky and Shpet, the goal of science instruction is to help students become fluent users of a sign system. From this point of view, instruction requires a sort of bootstrapping, in which students move from having little ability to use a sign system, to becoming fluent users of that sign system.

In my commentary, I will contrast the view of science learning outlined by Wertsch and Kazak with what I will refer to as the *conceptual change* perspective (e.g., diSessa & Sherin, 1998; Posner, Strike, Hewson, & Gertzog, 1982). The conceptual change perspective, understood broadly, is likely the perspective most widely held by researchers in science education. In very crude terms, the conceptual change perspective focuses on the nature of the knowledge that students possess in advance of instruction, and how that knowledge both impedes and provides the basis for future learning. In contrast, the perspective of Wertsch and Kazak emphasizes the properties of the sign systems that are to be learned, and the gradual process of enculturation into the use of these systems.

The endeavor I undertake here is intended to have a few benefits. First, I hope to do some of the work needed to situate Wertsch and Kazak's perspective within the main line of research on science education. In addition, I believe that productive competition between the conceptual change perspective and the perspective of Wertsch and Kazak holds the promise of enriching both.

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Review of the Wertsch-Kazak Perspective

At the heart of the perspective outlined by Wertsch and Kazak is a particular image of individual learning, drawn from Vygotsky and his intellectual predecessors. Wertsch and Kazak sum up this image as follows:

> . . . the general picture Vygotsky had was one in which thought is taken to be a relatively inchoate, 'fused, unpartitioned whole' that comes into contact with words, which involve generalization and discrete, sequential representation. (p. 154)

In this image, we are asked to imagine that, before thought comes into contact with sign systems, it is somehow unformed. Then, through contact with sign systems, the "fused, unpartitioned whole" becomes articulated; that is, it is broken up into discrete parts. Furthermore, because it is contact with sign systems that brings order to thought, higher mental functions should be understood to appear first on the intermental plane.

Starting from this Vygotsky-Shpet image of learning, Wertsch and Kazak go on to derive several implications for how we must understand learning interactions. Here, I summarize these implications in three points:

1. As stated above, Wertsch and Kazak argue that, from the Vygotsky-Shpet perspective, the goal of instruction is for learners to become fluent users of a sign system.
2. Wertsch and Kazak point out that learning must involve, at least initially, communication between instructors, who are presumed to be relatively fluent users of the sign systems, with learners who have little ability to make use of the sign system. This requires that a sort of bootstrapping must occur, where learners are somehow able to make use of the sign system (or at least, the associated sign vehicles) with only a limited understanding.

   > One of the properties of the sign systems that are at the heart of instruction is that they are incredibly robust in that they can allow interpretation and understanding at many different levels yet still support the intermental functioning required to move learning and instruction along. (p. 156)

3. Finally, because it is possible to interpret and understand instructional sign systems at many different levels, users of the sign system can "say more (as well as perhaps less) than what we understand or intend."

Taken together, these three implications, and the Vygotsky-Shpet perspective on which they are based, constitute the core image of science learning that is presented by Wertsch and Kazak. In this image, a learner interacts with other learners or a more knowledgeable other. To this interaction, the learner brings some undifferentiated thought. As the learning interactions begins, the learner may initially use sign vehicles without much intersubjective overlap with fluent users of the sign systems. Through participation in the learning interaction, the learner gradually becomes fluent in the sign system, and the undifferentiated thought is domesticated. This is made possible in part because the sign vehicles that are employed in instruction are precisely those that support this process; that is, they allow progress to be made with little intersubjective agreement.

Contrast to the Conceptual Change Perspective

I will now contrast Wertsch and Kazak's perspective, summarized above, with the conceptual change perspective that is prevalent in science education research. To do so, I begin with a proposal, made by Wertsch and Kazak themselves, for a possible way to revise and extend the Vygotsky-Shpet perspective. In the concluding section of their chapter, Wertsch and Kazak discuss constructivism, and they introduce what they call "socioculturally situated constructivism" (p. 165). I begin by looking at some features of how they define this term.

It seems that, for Wertsch and Kazak, constructivism is associated with *discovery* approaches to instruction – approaches to instruction in which learners are required to invent new knowledge by themselves. In this view, socioculturally situated constructivism differs because students are not required to do all of the inventing themselves. Wertsch and Kazak state: "From this perspective, students are invited to discover the meanings that can be worked out when using certain sign vehicles, but they are not invited to discover cultural tools themselves." (p. 165) Thus, the proposed revision of constructivism is "socioculturally situated," because learners are not expected to invent culturally developed tools, instead these tools become part of the backdrop against which sense making occurs.

Before proceeding, I must note that it is my belief that the version of constructivism implied by Wertsch and Kazak constitutes an over-association of constructivism with discovery learning. Constructivism is an epistemology – it is a very broad theory about the nature of human knowledge. As such, it is consistent with virtually any model of instruction. Second, and more importantly, no constructivist would ever expect individual knowledge construction to happen in a vacuum without help or interaction. The point of constructivism is precisely the point that Wertsch and Kazak make with respect to socioculturally situated constructivism, namely, that each individual must do their own work to make meaning with cultural tools as they learn. Thus, what Wertsch and Kazak call "socioculturally situated constructivism," I would simply call "constructivism."

The point made in the preceding paragraph really only concerns the specific words employed; it does no damage to the central points made in their discussion of constructivism. But I believe that Wertsch and Kazak's treatment of constructivism is indicative of a deeper, very important, attribute of their broader orientation. In particular, their central point is to emphasize that discovery and sensemaking take place in the context of existing cultural tools. What is simply not emphasized in their treatment of constructivism, is that an individual's sensemaking takes place against the background of everything else that the student knows.

Even if this is only a difference in emphasis, it is a profound difference in emphasis. As stated above, much of the focus of research on science learning has been on the knowledge that students possess prior to formal instruction. The orienting assumption, which has grounded a huge percentage of science education research, is that students enter any science instruction already knowing quite a lot about the natural world. This is assumed to be true for a number of reasons. First, in many cases, students have already had some relevant science instruction, either earlier in their academic career, or in more informal venues. Second – and of even more interest to conceptual change researchers – is the observation that we all learn a great deal about the natural world, just from our everyday experience with and discourse about the natural world. We drop balls, push pianos, pour beer, and heat muffins, and we also talk about these experiences as we go about out daily lives. In what follows I will refer to this informally gained knowledge of the natural world as *intuitive science knowledge*.

Though there is much debate in the conceptual change literature, there is also a substantial undercurrent of agreement. At the heart of this agreement is the belief that the biggest problems in science instruction relate to the nature and role of intuitive science knowledge. For example, some researchers have argued that intuitive science knowledge interferes with learning and must be replaced, while other believe that intuitive science knowledge must be reshaped and adapted (e.g., McCloskey, 1983; Smith, diSessa, & Roschelle, 1993). But, in either case, it is believed that some of the most central challenges faced by science instruction have to do with how intuitive science knowledge can be addressed.

Clearly this conceptual change image, of intuitive science knowledge that must be replaced or transformed, differs substantially from the image I associated with Wertsch and Kazak. For Wertsch and Kazak, there is little attention focused on the knowledge that exists as students enter into science instruction. This existing knowledge is unformed or "inchoate." As such, their perspective does not focus any attention on what attributes of this unformed knowledge might pose impediments to science learning, or what components might provide resources.

How "Inchoate" Is Intuitive Science Knowledge?

As discussed above, Wertsch and Kazak use words such as "inchoate" and "amorphous" to talk about the thought of an individual prior to beginning the path to fluency in a sign system. The appropriateness of this characterization has actually been a focus of discussion in science education and psychological research. The debate is relevant enough to this commentary that it is worth reviewing briefly.

The debate is essentially about the character of intuitive science knowledge. On one side of this debate are scholars who believe that intuitive science knowledge exhibits some substantial coherence and stability (McCloskey, 1983; Vosniadou & Brewer, 1992). This view is sometimes referred to as the *theory-theory*. On the other side of the debate is the *knowledge-in-pieces* view (diSessa, 1993; Smith et al., 1993). In this latter view, intuitive science knowledge is seen as consisting of a complex system of elements which are not highly organized, and which generate behavior that may depend sensitively on the context.

This debate has taken on a particularly clear form in the case of intuitive physics. On the theory-theory side of the debate are researchers such as McCloskey (1983), who have argued that intuitive physics knowledge consists of a remarkably consistent and articulately held theory. McCloskey, in particular, argues that prior to instruction, individuals hold a version of a theory known as the *impetus theory*, which, historically, was a predecessor to Newton's mechanics. On the other side of this debate is the knowledge-in-pieces view of intuitive physics, championed by diSessa (1993). diSessa describes a portion of intuitive physics knowledge that he calls the *sense of mechanism.* The sense of mechanism consists of a moderately large number of elements diSessa calls *phenomenological primitives* (or p-prims, for short). These p-prims are simple conceptual schemas that form the base level of our explanations of the natural world. They include elements that diSessa calls "balancing," "guiding," and "dying away."

Furthermore, although diSessa has given names to individual p-prims, he is careful to emphasize that p-prims are not necessarily associated with individual words in our lexicon. P-prims are not easily articulable, nor are individuals generally aware of their existence. Instead, they are part of the "gut feel" that we have for the mechanisms underlying physical events.

If the theory-theory view is correct, then the perspective outlined by Wertsch and Kazak will probably not provide much leverage in understanding the problems associated with science learning. If students possess alternative scientific theories, and these theories must be confronted and replaced during instruction, then it seems certain that these prior theories must figure prominently in our accounts of science learning. Wertsch and Kazak's perspective, as described in their chapter, is simply not set up to offer such an account. In contrast, if the knowledge-in-pieces account is correct, then the perspective of Wertsch and Kazak might be more productive; it might be reasonable to see increasing fluency with scientific sign systems as "domesticating" some amorphous intuitive science knowledge.

In some respects, this is consistent with the account of the development of physics expertise given in diSessa (1993), and that I myself have given (Sherin, 2001). In both cases, intuitive physics knowledge, in the form of p-prims, takes on increasing organization, and is mobilized to perform specific functions having to do with the use of the sign systems in physics, notably equations.

But some caveats are merited at this point. It is true that the knowledge-in-pieces view assumes that intuitive science knowledge consists of a large number of inarticulate and not well-organized elements. But this does not mean that it is so amorphous that it cannot be the focus of study. In fact, diSessa's (1993) 90 page article on p-prims is a detailed analysis of the contents and properties of the intuitive sense of mechanism. Thus, although "domestication" might be useful as a broad metaphor, it should not become a license for assuming that "inchoate" knowledge cannot be the focus of scientific study.

Furthermore, even if the knowledge-in-pieces view of intuitive physics is largely correct, it is manifestly obvious that there will be some cases in which students enter science instruction with well-developed and highly articulate knowledge, including facility with some formal sign systems. The instruction that occurs in schools rarely begins from ground zero. Rather, instruction in schools almost always builds on what students have learned previously in school. This makes it clear that the extreme version of Wertsch and Kazak's image, in which amorphous thought is domesticated, will rarely hold. Thus, Wertsch and Kazak's image must be amended to account for transformation of already-domesticated thought.

The Bottom Line

Where does this contrast of Wertsch and Kazak to the conceptual change perspective leave us? To a certain extent it seems that the difference is one of emphasis; in particular, there is a difference in the extent to which prior knowledge is a focus. But this difference in emphasis is entangled with some profound questions pertaining to how we understand the challenges of science learning.

At one extreme, some conceptual change researchers have conceptualized science learning as involving rationale competition. Learners are seen as possessing firmly held theories, and it is assumed they will only change these theories when faced with a rationale argument that favors an alternative. Although this extreme position is not the norm in conceptual change research, it is not only a straw man; this position enjoys a highly respected location in the research literature (Posner et al., 1982; Strike & Posner, 1992).

At the other extreme, is a view of science learning as involving a more organic development of fluency with sign systems. In this case, the primary challenge faced in science learning is not associated with confronting existing intuitive science knowledge; rather the challenge is the complexity associated with mastering the nuances of diverse semiotic conventions.

Of course, there is a huge middle ground between these two extremes, and I believe that the most useful perspective will strike the right balance. On the one hand, I believe that rationale between competing theories will rarely capture the difficulties of science learning. On the other hand, I do believe that understanding the nature of intuitive science knowledge, and its role in learning, will be important to developing a full picture of the challenges of science learning. Intuitive science knowledge might be "inchoate," but it is not so inchoate as to be un-analyzable.

Revisiting Wertsch and Kazak's "Illustrations"

In their chapter, Wertsch and Kazak apply the perspective that they lay out in two excerpts, drawing from the data corpus that is the focus of this volume (see Appendix B). In this section of my commentary, I want to reconsider these illustrations given my discussion in the above sections.

A few preliminaries are necessary. At the heart of my commentary have been issues pertaining to the prior knowledge possessed by learners. However, the prior knowledge that is relevant to the episodes discussed by Wertsch and Kazak is not the type of intuitive science knowledge that is typically a focus of conceptual change research. The scientific subject matter is, in some respects, about plants. However, student knowledge of plants is really not at issue in these episodes. Indeed, although the lessons that are the focus of this volume are described as being from a "science classroom," they do not address science content in the usual, more narrow sense. It is more helpful, I believe, to think of the focus of these lessons as being on scientific representations, and on certain statistical notions as applied to scientific data. Clancey (p. 269) makes a similar point, arguing that the activity is largely located in the "graph domain" rather than the "plant domain."

Does the conceptual change perspective make sense when goals are of this sort, rather than more traditional science content goals? I believe that the answer to this question is yes. Consider, first, the focus of the lessons on scientific representations. Just as students have a significant amount of experience in the physical world, they also have significant experience in a world populated by representations. Throughout their daily experience, children encounter representations such as photographs, diagrams, and text. Thus, just as they develop intuitive knowledge about the natural world, it is quite reasonable to assume that children acquire a significant body of knowledge about the representational world, knowledge that is relevant to learning about and designing new scientific representations. This general knowledge of the representational world has been termed *meta-representational competence* (diSessa, Hammer, Sherin, & Kolpakowski, 1991; diSessa & Sherin, 2000; Sherin, 2000).

In addition to meta-representational competence, there is also more specific representational knowledge that is relevant to the classroom lessons that are the focus of this volume. For example, it is apparent that students in the classes studied have experience with specific representational forms such as graphs of various sorts.

In addition to this existing representational knowledge, students possess intuitive statistical knowledge that is relevant to the illustrations discussed by Wertsch and Kazak. For example, it is likely that the students have an intuitive understanding of notions such as "typical" and "spread out;" indeed, the design of the instruction assumes that these intuitive understandings exist.

With these preliminaries addressed, I now turn to some details of Wertsch and Kazak's illustrations. They begin the first illustration with a description of how the task was described to the students. In doing so, they describe a number of "clues" given by the instructors as to what is expected of the students. One of these clues is that the students are supposed to determine what a "typical" plant is; they are also told they are supposed to determine "how spread out" the data are. More specifically, Wertsch and Kazak say:

> In this context, the term "typical," a term he repeats several times in what follows, has a special meaning. Namely, it points to a measure of the central tendency of a data set. And fifth, RL told the students they should be asking about "how spread out" the data are. In this context, the notion of being spread out reflects a concern with what is called the variability of data in the language of statistics. (p. 159)

Wertsch and Kazak suggest here that these clues are helpful because they point to where students are ultimately supposed to end up; for example, typical has a "special meaning," a technical meaning, associated with central tendency, and the idea is that students will move toward increasing appreciation of this technical meaning. But I believe that these clues are also useful because they tell students where to *start*; the word "typical" works as a clue precisely because this word has non-technical meaning for students. From the conceptual change perspective, students have an intuitive understanding of typicality, and the instruction is intentionally building on this intuitive understanding.

Again, to a certain extent, what I am proposing here might just be a difference in emphasis. However, I do believe that there are some issues of real import here; I believe that the perspective of Wertsch and Kazak leads them to systematically underestimate how much students understand, as well as how much intersubjective agreement there is among students and instructors. For example, as Wertsch and Kazak begin their description of the interaction between students and LS, they state:

> In the discussion that follows, it becomes quite clear that, at least initially, the students' understanding of how to use graph paper and how to organize the data, as well as their understanding of the terms "typical" and "spread out" have little overlap with that of the instructors. (p. 159)

And they add shortly later: "To be sure, these students were using the sign vehicle provided to them, but they clearly did not know how to use it as an expert would" (p. 159).

In these passages, I believe it is clear that Wertsch and Kazak are underestimating how much students know. They say that the students' understanding of how to use graph paper has "little overlap with instructors." But there is evidence throughout the lessons that the students know a great deal about graphs of various sorts. In fact, there is substantial evidence, even in the brief episodes recounted by Wertsch and Kazak. For example, when LS suggests making use of a "frequency table or histogram," [Excerpt 4, 0:24:24] Edith seems to understand immediately, and to see the merit of the suggestion. For this to be true, Edith must have some understanding of frequency tables and histograms. A similar event occurred near the end of the episode that Wertsch and Kazak described in their second illustration. As Wertsch and Kazak discussed, RL left the group with the admonition "Well, you gotta kinda figure out what you are trying to figure out, Okay, so fix it" [Excerpt 5, 0:41:44]. But he returned a short time later [Excerpt 6, 0:42:35], and began to lead the group through the construction of a frequency chart. Before he finished, Jewel suggested that they "draw a stem-and-leaf graph" [Excerpt 6, 0:44:13]. Again, this suggests that this student has some understanding of this very specific type of graph.

Thus, it is not the case that there is little overlap in "students' understanding of how to use graph paper and how to organize the data . . . with that of instructors." The problem is not that the students have no understanding of what a stem-and-leaf diagram is, at least not entirely. Rather, the difficulty seems to stem, at least in part, from the need for students to see that using a stem-and-leaf diagram in this context is a good idea, and to understand how it can be put to use.

Overall, my point here is that Wertsch and Kazak's image of learning, in which "inchoate" thought is domesticated through interaction with signs might lead us to systematically underestimate what students know, as well as how much intersubjective overlap there is between student and instructor. I want to point out one additional way in which Wertsch and Kazak might be underestimating intersubjective overlap. Here, I will focus on the statistical notions such as “typical” and “spread.” It is certainly the case that an expert will have more refined technical notions associated with these terms. But this does not require that the experts will have lost any sense of the associated intuitive notions. I expect that, in daily life, experts continue to apply intuitive meanings for these terms in much the way that the students do. In addition, I believe that these intuitive notion become part of the conceptual underpinnings of the more technical concepts possessed by the experts.

These observations are important because they point to additional intersubjective overlap between instructor and student. When the instructor says “typical” or “spread out” he has a reasonably good idea how these terms will be understood by students. Furthermore, when the student uses these words, the instructor likely has a good sense what the student means. On Day 28, for example, the teacher led a class discussion which centered, to a large extent, on the meanings of these terms. Different groups of students presented their representations, and the class commented on how well they showed the spread of values, and the typical value. In the following passage, for example, the teacher asked the students to indicate the “typical” Fast Plant on a graph. There is much to be worked out for the students to agree on how to apply the notion of typical-ness to the data. But the fact is that there is enough overlap on which to ground a discussion.

Excerpt 10 [0:20:47–0:22:03]

0:20:47	teacher:	= Ca can you guys circle on there where where wherever you guys think a typical Fast Plant is? by looking at the graph?
0:20:53	Ian:	I think would be somewhere in the middle.
0:20:55	(Cindy):	Wouldn’t it be somewhere ⌈(in the middle?)
0:20:57	(Ian):	⌊( )
0:20:59	Ian:	It would be like in the middle.=
0:21:01	teacher:	= Well yer okay Ian your saying the middle I saw Kerri ssa kept pointing to something with a with a ⌈(0.7) ⌈squares all around it. =
0:21:44	Ian:	=I think to find the um a typical one you’d look like toward the middle of the graph? and find a point that was closest to the middle? (0.7) because then up and down you’d find the middle and side to side you’d find the middle=
0:21:57	teacher:	=So would you say that yer >I think you said< the typical was probably this one or would it ⌈would you use
0:22:01	Ian:	⌊Somewhere around there.
0:22:03	teacher:	Okay.

The discussion in this excerpt shows that there is at least some intersubjective overlap between teacher and students around the meaning of terms like “typical.” This is likely part of what makes communication – and progress – possible.

Returning to the Larger Claims

I want to conclude this commentary by returning to the major claims made by Wertsch and Kazak. Perhaps the most central claim is the point I labeled as implication #2 above. The idea behind that claim is that sign vehicles can make it possible for a sort of bootstrapping to occur, where learners are able to make use of the sign vehicles with only a low level appreciation for the sign system, and with very limited intersubjective overlap with an instructor. In the conclusion to their chapter, Wertsch and Kazak restate this claim as follows:

> When using the graph paper in this context, two things become quite apparent. First, it is a cultural tool that allows novices and experts to enter into intermental functioning even when the two parties understand the task in very different ways. It is in this sense that the graph paper is a very robust material sign vehicle. It allowed LS and the students in Illustration 1 and another group of students in Illustration 2 to begin a discussion of what to do with the sixty-three data points at a very low level of intersubjectivity. But it is precisely this that then made it possible to move on to increasing levels of shared understanding of the data and how they are to be analyzed. (p. 164)

Given my comments in the preceding sections, there are several respects in which one might want to question this conclusion. First, I have attempted to call into question, at least to some degree, the assertion that there is “a very low level of intersubjectivity” in the episodes described. I argued that the students have some substantial knowledge about graphing, and that instructors and students share intuitive understanding of notions such as “typical.”

I also believe it is necessary to call into question the claim that the graph paper, and the low-level intersubjectivity it affords, “made it possible to move on to increasing levels of shared understanding.” Wertsch and Kazak make this point quite strongly. Following the above passage, they go on to state: “On the one hand, this process could get off the ground only because the robust nature of this material sign vehicle offered possibilities for establishing intersubjectivity at very low levels.” In contrast, I believe there is no reason to believe that, as implied there, the sign vehicle is either necessary or sufficient for this process “to get off the ground.” In my comments above, I hope to have made clear that the sign vehicle is just one of many features of the interactions that conspire to make progress possible. It also matters, for example, that there really is a great deal that is shared among students and instructors, such as intuitive notions of typicality, and understanding of different kinds of graphs.

However, I do believe that there are absolutely key insights in Wertsch and Kazak’s analysis. I want to conclude this essay by restating these key insights in my own terms, and proposing some final refinements. First, a central insight of Wertsch and Kazak’s analysis is that instructional interactions can require students and instructors to converse about subjects about which the student has little understanding, and about which there is therefore little shared understanding. How is this possible? Wertsch and Kazak's answer is that instructional sign systems have robust sign vehicles that allow progress to be made even with a very low level of shared understanding. But the conceptual change answer is somewhat different: One way that instructors make progress is by starting from ground in which there *is* relatively high intersubjective agreement, and by building toward the desired understandings.

To take a simple example, physics textbooks often introduce the notion of force by defining it as "a push or a pull." Technically speaking, this falls far short of a formal definition of force. Nonetheless, it makes a good place to begin instruction, because it's starts from a meaning that can be appreciated by student and instructor alike.

If material sign vehicles are not necessary and sufficient for the sort of bootstrapping that Wertsch and Kazak describe, do they have any special role to play? I believe that the answer to this question is yes; material sign vehicles can play a special and unique role. This is because material sign vehicles have properties that make it possible for instructor and student to, relatively quickly, establish a high degree of intersubjective agreement, at least about the limited world that they comprise. For example, when a student and teacher have a sheet of graph paper in front of them, this graph paper provides something they can talk about. They can discuss, for example, specific boxes on the graph paper, the edge of the sheet of paper, or any numbers written on the paper. Because the graph paper is immediately present, they can literally point to features on it. This can facilitate the gaining of high intersubjective agreement about the limited world that is present on the sheet of graph paper.

Material sign vehicles have other properties that make them useful in this regard. The surface of a sheet of graph paper is useful not only because it is immediately present; it also has the capacity for containing an essentially limitless variety of meaningful detail. It is essentially a surface on which miniature worlds can be constructed – worlds about which it is possible to develop high intersubjective agreement.

In conclusion, I believe that a contrast between the conceptual change perspective and the perspective adopted by Wertsch and Kazak helps to illuminate features of both. Ultimately, I believe that a meaningful synthesis will be possible, one that builds on the insights associated with each perspective.

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Chapter 12
From Dialectic to Dialogic

Rupert Wegerif

Introduction

A key claim in Wertsch and Kazak's paper (Chapter 9) is that "cultural tools have 'constraints' as well as 'affordances'" (p. 155) so I am sure that they would agree with me that, while their theory of learning as being taught how to use cultural tools illuminates some aspects of education, there are other aspects which it obscures. I have been influenced by Wertsch's work in the past and have found it useful in understanding and improving the way in which children are taught to think together through being drawn into particular ways of using language (e.g. Wegerif, 2001). However I have become increasingly concerned that this version of socio-cultural theory does not provide an adequate account of how children learn to think creatively. I suspect that this is because creativity originates in the dialogic relation, rather than in the use of pre-existing cultural tools. Wertsch and Kazak's paper is the position paper in a section of this book headed "dialogic theory of learning" yet in their paper they do not seriously discuss the issue of dialogic, pointing out that, since their theory is about "mediation", which is "the most basic conceptual category in the writings of Vygotsky", it is, therefore, about dialogue. I want to challenge the idea that dialogues in education can be adequately studied through a focus on mediation and the possible implication that Vygotsky was a dialogical thinker. Against these claims I will argue that accounts of learning dialogues in terms of their "mediating means" presuppose the prior achievement of a dialogic relation between people through which signs can be interpreted as meaning something and that, while Vygotsky could reasonably be called a dialectical thinker, he is not a dialogical thinker. Wertsch and Kazak are right to suggest that a focus on cultural tools is compatible with a dialogic account of learning but, in my view, a dialogic account goes further and so leads to a different overall understanding of the nature and purpose of education.

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Vygotsky as a Dialectical Thinker

I am always surprised when I read references in educational literature to Vygotsky as a "dialogical" thinker (e.g. Wells, 1999; Kozulin, 1986; Shotter, 1993). I can only imagine that the passages which leap out at me when I read *Thinking and Speech* (or *Thought and Language*), do not appear so significant to others. In Chapter 6, for example, Vygotsky affirms his commitment to a monologic philosophical position several times in terms which are so clear they could hardly be misunderstood. He uses the model of classical mathematics to suggest that ultimately concepts are all subsumed into a logical system which he refers to as a system of equivalences:

> The higher levels in the development of word meaning are governed by *the law of equivalence of concepts*, according to which any concept can be formulated in terms of other concepts in a countless number of ways. (Vygotsky, 1986, p. 199, emphasis in original)

He then uses an image of a global grid to affirm that this grid of concepts is a totalising system with an image rather similar to the current global positioning satellite network:

> If we imagine the totality of concepts as distributed over the surface of a globe, the location of every concept may be defined by means of a system of coordinates, corresponding to latitude and longitude in geography. One of these will indicate the location of a concept between the extremes of maximally generalised abstract conceptualisation and the immediate sensory grasp of an object – i.e. its degree of concreteness and abstraction. The second coordinate will represent the object reference of the concept. (Vygotsky, 1986, p. 199)

As I am not able to read Russian, and so cannot claim to be an expert on Vygotsky, I was, at first, a little concerned that my reading of Vygotsky did not apparently converge with the accepted interpretation. I was therefore pleased to find Jim Wertsch, who is an expert and a Russian speaker, acknowledging my more monological reading of Vygotsky in one article where he refers to Vygotsky as "an enlightenment rationalist" (Wertsch, 1996). However, Wertsch claims, there is ambivalence in Vygotsky's texts and the implication of his theory of signs as psychological tools often led him beyond a simple one-way street view of development. One theme running through Vygotsky's work is dialectical method and I think that this might also explain this apparent ambivalence. A key feature of dialectic in Hegel and Marx is that it attempts to integrate real dialogues and struggles into a logical story of development leading to unity either in the "Absolute Notion" of Hegel or the rational society under global communism of Marx. It is possible that Vygotsky engaged more with Hegel than with Marx (Van der Veer & Valsiner, 1991) and the influence of Hegelian dialectic is certainly very evident in many of his theoretical formulations. At one point Vygotsky implies that his whole approach to psychology can be described as the application of the Hegelian dialectic to the issue of individual cognitive development:

> Thus we may say that we become ourselves through others and that this rule applies not only to the personality as a whole, but also to the history of every individual function. This is the essence of the progress of cultural development expressed in a purely logical form.

> The personality becomes for itself what it is in itself through what it is for others (Vygotsky, 1991, p. 39).

The account he gives here of development from 'being-in-itself' to a more complex, self-related, 'being-for-itself' through the passage of 'being-for-others' is borrowed directly from Hegel (see, for example, Hegel, 1975, p. 139).

Dialectic and dialogic sound similar and often look similar. However making a distinction between them is important for some versions of dialogic theory. For those postmodernists influenced by Lévinas ethical critique of monological reason, including Derrida and Lyotard, dialectic was often seen as the worst kind of monologic precisely because it was monologic dressed up to look like dialogic (see Descombes, 1980, for an account of post-modernist thought as resistance to Hegel). The argument is that the 'other' which often appears in the dialectic algorithm, is not genuinely other at all but merely a prop for the development and expansion of the 'self', in the form of a totalising system of explanation and control. 'Difference', Lévinas claims, is posited only to be appropriated and reduced to 'equivalence' in systems of 'representation' (Lévinas, 1989, p. 77). Like Buber, Levinas was a Jewish theologian as well as a philosopher and he contrasted the "egology" of western rationalism to the "wisdom" of responding to the "infinite" call of face of "the Other," an infinite call that, he claimed, disrupts all totalising systems of thought.

While not as messianic as Lévinas, Bakhtin was similarly clear about the significance of the important distinction to be made between dialectic and dialogic:

> Take a dialogue and remove the voices (the partitioning of voices), remove the intonations (emotional and individualizing ones), carve out abstract concepts and judgments from living words and responses, cram everything into one abstract consciousness – and that's how you get dialectics. (Bakhtin, 1986, p. 147)

To paraphrase and repeat Bakhtin's main point here: dialectic is a dynamic form of logic leading all apparent differences to be subsumed into identity in the form of a more complexly integrated synthesis, it is not dialogic since dialogic refers to the interanimation of real voices where there is no necessary "overcoming" or "synthesis." I interpret the Vygotsky of *Thinking and Speech* as a dialectical thinker who gave dialogue a role in his theory of development. While he offers insights which have been read by some in a dialogic way, I think that it is misleading to refer to him as a dialogic thinker or to refer to his theory of education and development as a dialogic theory.

Learning to Use Cultural Tools as a Theory of Education

Wertsch and Kazak ground their theory of teaching and learning on what they call the Vygotsky-Shpet perspective which they claim can be found in the seventh chapter of *Thinking and Speech*, where Vygotsky writes about the development of word meaning. It is interesting, Wertsch and Kazak write, that Vygotsky gives such importance in this chapter to his "discovery" that word meanings change. This points us, they continue, to the way in which using signs often leads us to say more than we know that we are saying. So novices in a discourse may take up words that have complex meanings and use them with very limited understanding, but in a way that is sufficient for communication with teachers, who can thereby draw them up to more advanced levels of understanding. From this Wertsch and Kazak develop a more general theoretical position which is that all education is about "know how" rather than "know that" – specifically knowing how to use cultural tools appropriately and skillfully. The outcome of education, they say, is not individual cognition so much as distributed cognition between people and their cultural tools. The methodological challenge posed by this theory is the need to assess "how well students have mastered words and other semiotic means." Wertsch and Kazak illustrate how their theory helps us to understand the role of graph paper and key concept words in the Lehrer classroom data discussed at the Allerton workshop (see Koschmann, Chapter 1). In their analysis, cultural tools, such as words and graph paper, serve as a robust, yet flexible, mediating means, which enables intermental relations to be established even between people with very different levels of understanding.

Although Wertsch and Kazak base their theory on Vygotsky I am sure that they would agree that their reading is necessarily a selective one due to the ambivalence in Vygotsky referred to often by Wertsch (1985, 1996). It is therefore worth saying more about what Vygotsky himself might have meant by the idea, that is perhaps implicit in his work, that we say more than we know when we use words. In Chapter 7 of *Thinking and Speech*, Vygotsky makes a distinction between a word's proper meaning and the contingent "sense" of words that stems from the associations that they form from the ways in which they are used. The "meaning" of words for Vygoksky is, he repeats several times, a "generalisation or a concept". In earlier chapters of *Thinking and Speech*, Vygtosky outlines the development of the meaning of words from contextualised and concrete uses (syncretism) through fuzzy generalisations (complexes) to proper concepts (Vygotsky, 1987; also see commentary by Van der Veer & Valsiner, 1991, p. 263). The higher stages of concepts are characterised by more abstraction and generalisation (Wertsch, 1996, p. 25) while the lower are characterised as based upon more contingent, concrete and fuzzy criteria. Vygotsky described the initial stage of children's thinking as "participatory," a style of thinking which Vygotsky claims that children share with primitive people and with schizophrenics (Vygotsky, 1986, p. 236), while the highest stage of thinking is characterised as abstract rationality exemplified by the "law of equivalence," which I quoted above.

From this account of the development of concepts, it would make sense if Vygotsky were to suggest that we mean more than we know that we mean when we begin using potential concept-words, because, simply by using them, we are taking the first step on a one-way journey that will lead us all the way up into pure reason and scientific thought. "Sign-vehicles," on this theory, act like a kind of ski-lift for development; children can latch on to them while still in the valleys of concrete thought ("schizophrenic," "primitive" and "participatory" thought, let us not forget) and be lifted by them to the higher-altitude universal abstractions of reason and science. According to Vygotsky, the mechanism that drives this ski-lift is formal education. In the zone of proximal development teachers engage with children in order to train their spontaneous concepts into the already laid down routes of scientific concepts.

Wertsch and Kazak sum up their theory with the formula:

> the act of speaking often (perhaps always) involves employing a sign system that forces us to say more (as well as perhaps less) than what we understand or intend... (p. 156)

The addition here, of the small escape clause “as well as perhaps less” in brackets, shows their caution in relation to Vygotsky’s ski-lift theory of development. But can Vygotsky’s theory survive transplantation if the intrinsic telos of concepts towards abstraction, generalisation and truth is removed? What is the value of a ski-lift that does not carry us up a mountain? As Wertsch and Kazak themselves point out, words can mean more than we know because of the way that others interpret them and so they can also sometimes mean less than we know or they could be taken to mean something completely different. Certainly words like “histogram”, which figure in their account of the classroom data, have a dictionary meaning, which the teacher leads the students towards, however without the modernist meta-narrative of progress towards truth, the proper meaning of such terms is presumably left to be defined by the curriculum. The same approach could be applied to teaching any content whatsoever including, for example, scholastic doctrine about the numbers and the powers of the Cherubim and Seraphim in medieval Byzantium or Nazi accounts of the physiological differences between Aryans and Jews. This theory accounts for how we teach defined meanings in the existing curriculum, but it does not appear to offer a place for the development of new meanings through critical thinking and through creativity.

Two Triangles for Thinking About Dialogue and Development

In *Vygotsky and the Social Formation of Mind*, published in 1985 (pp. 64–65), Wertsch offers a rather similar theory to that presented by Wertsch and Kazak in 2005, but this time the vehicle is not Vygotsky’s account of word meaning, but his account of children learning to point. First the baby tries to grasp at something it wants, say a rattle, then the attentive mother gives it to the baby and so the baby learns that merely pointing at the object will draw the attention of the mother and so achieve its purpose. In 1985, Wertsch (quoting Wertsch & Stone, 1985) argued that this shift from using signs in a relatively ignorant way to using them in a more conscious way is generally the case with learning how to use cultural tools. However, in the case of learning how to point, it is clear that the mysterious force of language as a whole does not need to be invoked: the infant is carried beyond herself to mean more than she knows, through the attentive response of her mother. This learning to point takes place in the context of a mutually responsive relationship or “couple” between mother and child. It is through taking the perspective of the mother that the baby learns to understand that her own grasping gesture can be perceived as pointing and so, reversing perspectives again, she can learn to understand the gestures of her mother as pointing.

The self-other-sign triangle that sums up these relationships is a representation used by developmental psychologist Peter Hobson to explain how it is that infants first learn to use symbols. Hobson argues that what is crucial is an initial dialogic relationship with their mother (or other primary care-giver) which enables them to see things from at least two perspectives at once (Hobson, 2002; Hobson, 1998). If an infant sees a toy that makes them nervous they immediately turn to their mother and see that she has a different response to the same toy. If they now pick up the toy they do so with two emotions in mind, their own initial reaction and that of their mothers. Later, and this is the significance of Hobson's curved dotted line in the triangle, they learn that by taking a different perspective, the perspective of another person, they can create symbols, using one thing to stand for another, a piece of paper for a doll's blanket perhaps. Hobson claims that early dialogic relationships in which we learn to see from two perspectives, beginning with smiles and peek-a-boo games, are the origin of creative thought because they open up what he calls "mental space," a space of possibilities through which things become thinkable and bits of the world (sign-vehicles) become tools for thinking about the rest of the world. Thinking, on his account, is essentially a process of taking multiple perspectives – even if we only have one thought about something, he writes, it is the possibility of taking other perspectives that makes that thought thinkable.

Hobson's account suggests a different dialogic triangle from the famous subject-tool-object triangle that is often taken to underlie the sociocultural notion of mediation.

A possible response to the claim that we understand signs by taking the perspective of other people is that we only know the perspective of others through interpreting their signs. However, the signs involved in Hobson's account of the origin of symbolisation, smiles and emotions, are not tools for working on an object but part of a relationship with a person, indeed they are parts of that embodied person. Once we start saying that smiles are "signs" of a feeling or a person then we quickly get into the familiar philosophical problem of locating the person independently of their signs often referred to as the problem of Descartes' homunculus or the little person inside the person pictured as pulling all the levers. Wittgenstein writes in this context:

> We do not see facial contortions and *make the inference* that he is feeling joy, grief, boredom. We describe a face immediately as sad, radiant, bored, even when we are unable to give any other description of the features'. (Wittgenstein, *Remarks on the Philosophy of Psychology*, quoted by Hobson 2002, p. 243)

From the inside of a parent-baby "couple" the baby's smile is not taken as a sign of an inner state but is experienced as a radiance and is hard to distinguish from the answering smile. Interpreting that same smile as a sign that refers to an inner state of the baby already implies taking an outside perspective. Taking an outside perspective can be useful, as Garrison (Chapter 18) demonstrates when he explores the physiological basis of some facial expressions, but from a dialogic point of view, it is only possible to take this outside perspective on the basis of an inside perspective that is always prior and presupposed, although often not acknowledged.

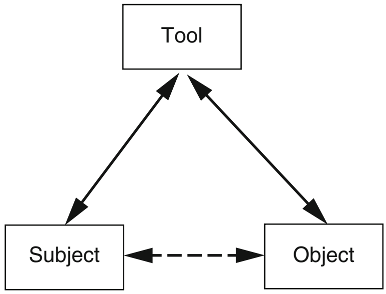

Fig. 12.1 Subject-Tool-Object mediation triangle

The argument here about a modest difference between two triangular representations of "mediation" has implications for theories of development and of education. Wertsch and Kazak's theory is that the use of cultural tools carries us beyond ourselves. This seems to follow from Fig. 12.1, the subject-tool-object triangle, as does their idea that the aim of education is to draw learners into the effective use of cultural tools. An alternative approach is that we are carried beyond ourselves by learning to take the perspective of other people. This is represented in Fig. 12.2, the self-other-sign triangle. On this, in my view, more genuinely dialogic account, language and culture are seen as an inexhaustible field of possible perspectives that open up in the space between people in dialogue. These two perspectives are reconcilable if it is recognized that dialogic relations between people provide a context for using tools, however mediation by cultural tools and dialogic relations are not, as Wertsch and Kazak imply, equal and reversible perspectives: dialogic relations precede and exceed tool use and are not reducible to tool use.

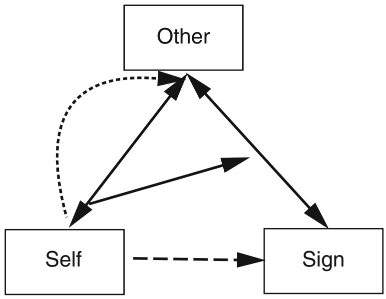

Fig. 12.2 Self-Other-Sign "dialogic" triangle

Definitions of "Dialogic" and Theories of Education

In this paper I have already used the term "dialogic" in a number of different ways with out pausing to define them. There are at least four different but interlinked ways of understanding dialogic, all of which can be traced to the writings of Bakhtin and all of which have implications for education.

Dialogic as Pertaining to Dialogues

Bakhtin defined dialogues as "inquiry and conversation" writing that "if an answer does not give rise to a new question from itself, it falls out of the dialogue" (Bakhtin, 1986, p. 114 and 168, quoted in Alexander, 2000, p. 520). This usefully distinguishes dialogues from social conversations without obvious educational significance on the one hand and monologues, the products of a single voice, on the other. Dialogic defined as pertaining to dialogue sounds like a straightforward ordinary language definition but raises certain problems which point to the need, in some contexts, for a more specialist definition. Bakhtin developed his account of "dialogic" out of a reading of Dostoevsky's novels which, as the work of one author, do not qualify as dialogues in the everyday meaning of the term. There are not many theories of learning that do not include a role for dialogues, including that of Piaget, but if this makes them all "dialogic" then "dialogic" is no longer a very useful term for characterising theories of learning. The meaning of dialogic for Bakhtin was not primarily a reference to an empirical area of investigation, that is to researching actual dialogues between people, but more a way of reading texts.

Dialogic Utterances Opposed to Monologic Utterances

Bakhtin described several ways in which texts and utterances could be located on a dialogic to monologic continuum, for example they can be more or less multi-voiced and they can be more or less open to the other. This description of texts and utterances relates to a contrast in types of orientation to the other first articulated by Buber who distinguished between an "I-thou" orientation to the other in dialogue and an "I-it" orientation (Buber, 1923/1970). The I-thou orientation is characterised by listening and understanding while the I-it orientation objectifies the other and is ultimately about controlling the other. Buber's contrast is echoed in Bakhtin's account of the difference between the "authoritative" voice that remains outside of my words and the "internally persuasive" voice. Bakhtin's account of the impact of what he called "the persuasive word" gives this an educational significance:

> Such a word awakens new and independent words, organises masses of our words from within and does not remain in an isolated and static condition: it is not finite but open; in each of the new contents that dialogise it, this discourse is able to reveal ever new ways to mean. (Bakhtin, 1981, p. 343)

Wertsch (1991) refers to this contrast between the "authoritative" and the "persuasive" in *Voices of the Mind* and relates it to a theory of learning as appropriating the voices of others based on Bakhtin's own account of how we appropriate the words of others:

> The word in language is half someone else's. It becomes "one's own" only when the speaker populates it with his intention, with his own accent, when he appropriates the word, adapting it to his own semantic and expressive intention. (Bakhtin, 1986, pp. 293–294).

Wertsch's synthesis of Vygotsky and Bakthin in the idea of learning as the appropriation of social voices and social discourses has been influential. However the philosophical frameworks of Bakhtin and Vygotsky are so different that this "synthesis" may be problematic. On Wertsch's model, the voices of others are treated as if they were cultural tools to be acquired and used by learners. The problem with this is that voices are "I-positions" (Valsiner, 2004) and so are also agents of a sort. If "mediating means" are voices then this must raise questions as to what exactly is meant by Wertsch's repeated assertion that the most basic unit of analysis is "an agent acting with mediating means."

Dialogic as an Epistemological Framework

While some of Bakhtin's characterisations of the dialogic features of utterances contrast with monologic, others refer to all utterances. In particular he claims that all utterances are a response to a situation or to somebody else's utterance and are addressed to somebody who is supposed to do something with them (Morson & Emerson, 1990, quoted by Linell, 2003). According to Rommetveit (1992) and Linell (1998, 2003) dialogism is a "paradigm" or "an epistemological framework" that makes a number of assumptions, three which I have selected as being central:

1. that any communicative act is interdependent with other acts, it responds to what has gone before and anticipates future responses;
2. that acts are similarly "in dialogue" with other aspects of context such as cultural traditions and social setting and,
3. that meaning does not exist "ready-made" before dialogues but is constructed in dialogues (which may well be the internal dialogues of thought).

In referring to this as an epistemological framework, Linell is saying that dialogic it is not about how the world "is" so much as about how we come to know things.

Dialogic as Ontology: A Postmodern Reading

Dialogic as epistemology often appears to assume an implicit ontology of subjects facing an objective world which they come to know about through talking together. A more radical step is to understand subjects and objects as already intrinsically dialogic. Bakhtin made it clear, in the context of a reading of Doestoevsky, that he intended to question the philosophical principle of identity:

> A human being never coincides with himself. The formula of identity "A is A" is not applicable to him. (Bakhtin, 1973, p. 48)

Sidorkin relates Bakhtin to Buber and claims that dialogic is not only about epistemology, or how we know things, but is also an ontology, asserting that the "essence" of being human (or human being) is not some kind of identity such as "a self" in the face of "a world" but the opening of dialogue (Sidorkin, 1999). The self, for Bakhtin is defined through dialogue and is at its most authentic as the opening of a difference between perspectives.

The idea of dialogic as an opening of a difference that is the source of meaning relates Bakhtin's dialogism to the postmodern theme of difference. Although perhaps best known in the form of Derrida's "différance", this postmodern theme can be traced back to the later Heidegger's lectures on "Identity and Difference" where he questions what he calls the "A = A" principle of identity thinking and finds the origin of meaning in an unmediated "ontological difference", the difference between Being and beings (Heidegger, 1969). Heidegger's account of this ontological difference is also an account of how mankind and Being belong together in what he calls "the event of appropriation" (*Ereignis*) which he describes as a movement of "overwhelming" and "arrival" and as the circling of beings and Being around each other (1969, p. 69).

Heidegger's language here may seem a little obscure but Merleau-Ponty, whose later work was very much influenced by Heidegger, offers an illustration which I find helpful. As I stand out in a landscape a horizon forms around me (I interpret this as Heidegger's "arrival") but at the same time as I create this horizon around me I also find myself placed as an object within this horizon (which I interpret as Heidegger's "overwhelming"). Merleau-Ponty refers to these two sides together as a "chiasm," a term that has been taken up by some dialogical theorists. The word chiasm is borrowed from grammar where it refers to the reversability of the subject and the object in a sentence and is used by Merleau-Ponty to refer to the mutual envelopment and reversibility between two total perspectives on the world around an unbridgeable gap or hinge which is also a "pure opening" of meaning. The unmediated "difference" (*écart*) at the heart of the chiasm is "ontological" because it is not simply a difference in a pre-given world but it also creates that world. Merleau-Ponty is particularly relevant to the ontological understanding of dialogic as he applies his figure of the chiasm to empirical dialogues and particularly to the phenomenon that Wertsch and Kazak foreground, which is being surprised to find that one knows more than one thought one knew in a dialogue (Merleau-Ponty, 1968, p. 15 and 113; Merleau-Ponty, 1964, p. 29 and 159). Merleau-Ponty argues that an implication of his ontology is that thought should not become stuck with representations of an objective world of things on one side, or with representations of a subjective world of ideas on the other, but remain in the opening between these two perspectives using "*surrefléxion*" (hyper-reflection) to grasp representations in their full context, a context which includes the implicit whole of being as the background to every fore-grounded figure. There is a fascinating similarity between the ontology proposed by Heidegger and Merleau-Ponty and the ontological interpretation of quantum theory proposed by the theoretical physicist, David Bohm. Bohm became an advocate of dialogue as a way of enabling creative thought, which he described in terms of a "holomovement," uniting the explication (unfolding) and implication (enfolding) of a background implicit wholeness (Bohm, 1996). Through the advocacy of Senge, Bohm's ontology which leads to an account of the opening of dialogue as a way of enabling creative emergence, has had an impact on the practice of organisational learning (Senge, 1993).

Implications for Models of Education

Each of these four ways of understanding dialogic has implications for education. Dialogic as pertaining to dialogue suggests the promotion of dialogue as chains of questions in classrooms both through teacher-pupil dialogues (Alexander, 2004) and through establishing communities of inquiry (Wells, 1999). Dialogic as being about the open and poly-vocal properties of texts brings in the need for intertextuality in classrooms (Maybin, 1999; Kozulin, 1996; Matusov, 2007) and the appropriation of social discourses as a goal in education (Hicks, 1996; Wertsch, 1998). Dialogic as an epistemologic framework suggests an account of education as the discursive construction of shared knowledge (Mercer, 2000). While all of these approaches to teaching and learning have been referred to, quite reasonably, as dialogic they could have developed without dialogic theory. In fact, in most cases, they have: Socratic dialogue, communities of inquiry and learning as mastery of particular genres of talk are not uniquely "dialogic" methods. Dialogic as an ontological principle, however, has more radical and original implications. Heidegger points out that the most important thing to be learnt is learning itself and, to achieve this, teachers need to be even more teachable than their students (Heidegger, 1978, p. 380). Another way of expressing this same point is that dialogue is not primarily a means to the end of knowledge construction, but an end in itself, the most important end of education (Sidorkin, 1999). In my view the ideal of "teaching" learning to learn through promoting dialogue as an end in itself is the most distinctive and important contribution that a dialogic perspective brings to the debate about education (Wegerif, 2007; Wegerif, 2010).

Dialogic and Researching Learning Practice

From a dialogic perspective the project of this book, to apply a range of different theories embodying different ideals as lens through which to analyze a single body of data, is problematic. As Packer (Chapter 10) points out the data given is not value neutral but is already informed by the educational ideas and ideals of the researchers, teachers and others who produced the educational practice and recorded it. The various theories of teaching and learning explored in this book are not neutral methods but also embody ideals of what education ought to be. So part of what we actually get when the data is "analysed" from a theoretical framework is a conversation between perspectives, however this form of conversation is a very unequal one in which one side, "the theorist", measures the recorded behaviour of teachers and learners and congratulates them or criticises them according to whether or not they fit the theorist's perspective embodied in a theory of learning. There is an ethical imperative in a dialogic approach which suggests that a more genuine engagement with the perspectives of practitioners and children is required in research on educational practice.

However, having expressed that concern, I find some of the micro-analysis of interactions in this book very insightful in exploring what look like fundamental processes of teaching and learning. By "fundamental processes" I simply mean processes which are not a product of a particular theoretical perspective but are relevant from a range of perspectives, including the perspectives of practitioners and of learners. Wertsch and Kazak's focus on cultural tools, for example, leads to a useful account of how teachers draw children into the desired use of graph paper. The focus on the dialogic relationships between people within which learning occurs, which I propose in this paper as a corrective to Wertsch and Kazak's focus on tools, does not aspire to replace this account but to augment it. To show how this might work in practice I will re-visit in turn each of Wertsch and Kazak's illustrations.

Illustration 1: Teacher–Student Interaction

This illustration demonstrates the practical value of Wertsch's synthesis of Vygotsky's Zone of Proximal Development idea and Bakthin's idea of the appropriation. It is based upon events that occurred on Day 26 (see Appendix B) when LS worked with the members of Group 3, Edith, Jasmine, Tyler and Kendall [Excerpt 4, 0:20:51–0:32:25]. If the pedagogical objective is to teach how to use histograms, as it seems to be here (see Greeno, Chapter 3), then there is little point just modelling how to make histograms because this will not be taken in by the learners. The best way to teach this is to engage students in the problem for which histograms are a solution, that is the problem of representing a spread of data in a way which makes finding typical values possible, and then, once they have struggled with this problem, to offer them histograms as a solution to what has now become "their" problem. This is exactly what we see happening in this extract. The students engage with the problem and eventually the teacher uses the groups shared focus on the graph paper as a way of guiding them to the solution – histograms. When the solution is offered the whole group appear to understand how it solves their problem and they seem pleased with it and even grateful to the teacher for giving it to them.

The teacher here sits as part of the group, seeming to hunch down so that she does not tower over the children, often with her hand over her mouth. When, 23 min into the activity, she moves to propose a way forward, she does so in a very tentative and hypothetical way, her hand hovering over the graph paper as if very unsure and working out the solution as she goes along.

If you look at Excerpt 4 [0:24:14–0:26:18] LS's tentativeness is very marked in the transcript. There is frequent use of phrases indicating uncertainty as to how to go forward such as "I don't know" and "Let's think", "kind off" and "maybe" as well as many pauses. This attitude contrasts markedly with the certainty she expresses in her notes for this day when she writes:

> These kids seemed incredibly clumsy with organizing this rather large data set (larger than we've seen before). Even putting the numbers in serial order was difficult and time consuming for these kids.

This contrast in the texts suggests that her tentativeness, either consciously or intuitively, was intended to open up the text of her speech to the others. Her pauses were not empty, they were filled with the facial expressions of the children in the group, showing their comprehension or lack of it. The teacher constantly searched their faces to check their response and everything she said was tailored to that response. At first she sees from their faces that they don't understand so she apologises and tries again.

Excerpt 4 [0:24:44–0:24:48]

```
0:24:44 LS:        I'm not making myself very clear, am I?
0:24:45 Jasmine:   Hha ha I don't know what you're talking about
                   actually.
```

This second time she succeeds in drawing them into her perspective partly by pretending that she does not know what she is doing and modelling the process of working it out from scratch.

Excerpt 4 [0:24:58–0:25:40]

```
0:24:58 LS:        Well I wasn't very clear (.) I was thinkin'
                   (.) we certainly don't have two hundred and
                   twenty five numbers across here (.) but if
                   we said let's use a square and put all the
                   ones that go from say thirty tah:: to fifty
                   or sixty and then: every time we see a number
                   we could put an X above it?
0:25:17 LS:        You understand what I'm saying?
0:25:18 Edith:     Yah-
0:25:19 LS:        It would give a line of Xs for all: the
                   numbers between thirty and sixty
0:25:24 Edith:     ⌈and then could like (.) °for°
0:25:24 LS:        ⌊And then we'd have another square between
                   sixty and ninety=
0:25:28 Edith:     =and then we could do ninety blahblah
0:25:30 LS:        Or maybe we could do it with twenties I don't
                   know lets count, twenty forty sixty eighty
                   one (.) ten- twenty forty sixty eighty. That
                   would be (.) maybe we could even do it by
                   tens↑.
```

The children join her in working it out, following her gaze and her gestures as she approaches the graph paper. When she counts the lines on the graph they were all counting together (at least those whose mouths were visible), moving their lips in unison with her words. After this she says:

Excerpt 4 [0:25:58–0:26:01]

```
0:25:58 LS:        ⌊Well that's one way of doing it but I don't
                   know if it makes sense to you guys?
```

And this time they all seem to get it and the children start talking now, making explicit how they are going to set about doing the graph.

The teacher is not the only one contributing to the construction of the dialogic space in the group. Clancey brings out well (Chapter 15) how the humour in this group, mainly originating with Tyler, implies holding more than one perspective at once and so loosens the grip of identity thinking and facilitates the flow of new meanings (see my account of "playful talk" as a source of creativity in Wegerif, 2005). Edith also contributes actively, supporting the teacher and sustaining her with her smiling gaze and her agreements. Twice Edith starts talking at the same time as the teacher and carries on in parallel to the teacher for a while. Just looking at the transcript it might appear as if she is trying to take the floor and is being drowned out by the dominant voice of the teacher but on the video it looks more like this is a supporting voice, Bakhtin's "answering words" that run parallel to the words of the other as we appropriate the voice of the other into our voice.

The central role played by the graph paper in this episode might be related to the fact that a particular use of this graph paper is the teaching objective of the activity. Wertsch and Kazak claim that the graph paper, as a "sign-vehicle" and robust cultural tool, is facilitating the creation of intersubjectivity between teacher and children. However, in her notes on the day LS seems to think that the graph paper might have been a problem.

> Maybe passing out graph paper was the source of some of the confusion, for example, kids looking for ways to make coordinate systems. The graph paper, coming in close conjunction with the recent graphs of the wicking, may have pushed some of the kids in that direction.

It seems that the children might have been misled by what they saw as the "affordance" of the graph paper for plotting co-ordinates. This reminds me of the similar issue that often arises with key words in teaching science. Everyday words, like "force" are given a special meaning in science which leads to confusions. Teachers often complain that it is much easier to teach a new concept with a new word that is untainted with everyday associations. While, clearly, the children are being taught how to use a cultural tool, it is not obvious that it helps to maintain intersubjectivity at different levels of understanding, this is the job done by the dialogic relationship established between teacher and learners. The teacher has to lead the children to lift their attention from the graph, which seems to speak to them of co-ordinates, in order to carry them along a different path with her voice, her gaze and her gestures.

It is not obvious to me that all learning is learning how to use cultural tools, as Wertsch and Kazak claim. What if the pedagogical objective was something quite different such as learning that "the Battle of Hastings took place in 1066" or "learning how to love"? From a more dialogical perspective, what is general to many types of learning is the importance of establishing a "robust" dialogic relationship between teachers and learners, or between groups of co-learners: relationships between people that are capable of sustaining within them different levels of intersubjective understanding about the pedagogical aim, whatever that happens to be.

Illustration II: Student–Student Interaction

Wertsch and Kazak's second illustration is based on Excerpt 3 [0:11:10–0:18:54] and Excerpt 5 [0:39:15–0:44:30] both on Day 26 in Appendix B. Here they seem to argue that a group of children do not really know what they are doing until a teacher comes along and, using the graph paper to support intermental engagement, steers them in the right direction. As Packer points out (Chapter 15) this account does not do full justice to the efforts that the group make to sort out their different perspectives and to find a shared way forward before the teacher arrives. They seem very engaged with the task, challenging freely, responding to challenges with reasons and struggling hard to find ways to understand each other. At one point there is a dramatic transition when April suddenly sees a point that Jewel and Wally have been making, which is, if I have understood it correctly, about how the structure of the graph can indicate information so that each data point on the graph does not need to be fully labelled. At this transition there is an evident release of tension from their faces and bodies and what Packer refers to as a "marking and celebration" of their achievement.

Changing one's mind in an argument is a very interesting phenomenon and could perhaps serve as a focus in any analysis of the micro-genesis of understanding in dialogue. April precedes her change of mind by listening intently to Jewel then turning her head away from Jewel a little, as if for a moment of private thought, then she lifts her head slowly with a long drawn out "Ohhh!" `[0:18:20]` her eyes widen as her mouth opens into the "O" shape which is at the same time a kind of smile. I assume that this dramatic enactment of a new understanding is cultural in origin but I don't really know that and the physiological basis of opening ones eyes wider in this way would be interesting to explore (see Chapter 15 by Clancey and Chapter 18 by Garrison). Is it the argument that Jewel has just given that enables her to see things so differently? Just before April's conversion experience there is an important bit of physical acting.

Excerpt 3 [0:18:07–0:18:19]

```
0:18:07 Wally:        =Okay Anneke, Anneke, Anneke Okay.
                      Fifty-three numbers? Okay. that would be
                      telling them with the graph. That's why
                      were making the graph.
0:18:15 Jewel:        We're saying it's Day Nineteen what (.)
                      how is it going?
```

As she says this last utterance Jewel makes an exaggerated welcoming gesture with her hand drawing in an imaginary viewer to look at the graph.

It seems likely that April's change of mind does not stem from the force of any abstract logic so much as from a shift in perspective to see the graph from a projected future point of view – the point of view of the addressee of the graph as a vehicle for communication. The signs that lead to this change of mind are not "tools" but "epiphanic" signs (Leimann, 2002) on the model of the invocation of a voice, for example the gesture of drawing in the alternative perspective.

There was also some loss of face involved in this change of mind. Jewel immediately sits down and says "Finally!" smiling smugly up to the camera. April then feels obliged to dispute Jewel's implicit claim to have caused her change of mind, saying, "You weren't making that point!" [0:18:33] wagging her finger at Jewel.

Clearly there was something at stake for her in not changing her mind and yet she found herself forced, almost despite herself, to see their point. In the act of changing her mind she is divided within herself. A dialogical account of the self from Hermans, Kempen, and van Loon (1992) or Valsiner (2004) would suggest that there are multiple I-positions at play and that the change of mind itself is a bit like a political "coup" as one group take over control of the main means of expression. However the leverage that enables this does not come from the graph paper here but from the idea of the addressee of the finished graph considered as an outside and future perspective projected forward from the dialogue and yet influencing it from within.

The quality of the relationships in the group is crucial to this achievement of unforced agreement. Although there is an element of what Mercer calls "disputational" talk in this group, which is conversation as a kind of competition which participants try to win and lose (Mercer, 2000) I think it is also "exploratory talk" illustrated by the fact that reasons are given and minds can change. Types of dialogue can be characterised through intersubjective orientations and shared ground rules (Wegerif & Mercer, 1997). The ground rules operating in this group mean that challenges are responded to with reasons, not with any breakdown of communication, and that changes of mind are possible, although, as we have seen, quite hard to negotiate without loss of face.

As Packer points out, this group work constructively together and do seem to be learning about perspective taking and about the affordances of graphs. However they are perhaps not learning fast enough, from the point of view of the teachers, about how to use histograms. Eventually [Excerpt 5, 0:39:15] an adult, RL, intervenes to point them in the right direction. He is not part of the group but stands to one side (see Fig. 12.4). Greeno points out that his intervention lends a teachers authority to one side in a debate within the group, Anneke's side against Jewel's side. Although the learners do take on board his suggestions they do so in a very different spirit from the way in which April changed her mind in the face of arguments from Wally and Jewel. In the first "change of mind" incident Jewel is excited and fully engaged with the task, as are the others. After the teacher intervention, however, she sits back looking disengaged and says, "Well who wants to erase all this, I don't wanna" [Excerpt 5, 0:41:50] (see Fig. 12.6).

Fig. 12.3 LS: "Well, that's one way of doing it." (Excerpt 4)

The increased slurring together of syllables in her speech matches her body posture and facial expression. The impression is that, for Jewel at this moment at least, the adult's guidance here leads to resistance rather than to appropriation.

Both Packer and Greeno appear to argue that RL's intervention here is in some way authoritative. Macbeth (Chapter 4) also appears to question this with a detailed analysis of a carefully transcribed section of a short section of talk between the teacher and the group showing how skilfully he engages them. Macbeth's analysis is convincing, but it is possible that, in interpreting the dialogue here, the salient factors are not present in the text alone. If we compare Fig. 12.3 with Fig. 12.4, it is immediately apparent that the adult in the second example is not positioned as part of the group because he is standing to one side and towering over them. Of course this is only one incident in a continuing relationship. When RL returns to the group it is noticeable that he squats down to be at their height. However, small incidents can be revealing of how dialogic relations support or hinder understanding. If we compare Fig. 12.5 with Fig. 12.6 I think that we are seeing something of the different effects on learners of what Bakhtin calls the internal, persuasive voice as opposed to the outside, authoritative voice.

Fig. 12.4 Jewel describes her approach to representing the data (Excerpt 5)

Fig. 12.5 April's enactment of a new understanding. (Excerpt 3)

Fig. 12.6 Jewel: "Well who wants to erase all this, I don't wanna." (Excerpt 5)

Discussion and Conclusion

Wertsch and Kazak are persuasive that, in the data this book is based around, children are being led to use a cultural tool appropriately. However, my provisional re-analysis of their provisional analysis, suggests that this kind of learning takes place through dialogic relations within which people can interpret each others' signs and take each others' perspectives. It is the quality of these relationships more than the robust nature of the cultural tool that determines whether or not the teacher's words are successfully appropriated. Clearly the focus on the role of cultural tools in Wertsch and Kazak's analysis, and my focus on the dialogic relation, can be combined. However, as a general account of education, Wertsch and Kazak's focus on the role of tools seems to be limited in a way that a focus on dialogic relations is not.

The best way to research a dialogic ideal of education, education in which dialogue is an end and not simply a means, would be through design studies of teaching informed by this ideal, not through the re-analysis of teaching informed by different philosophical ideals and with different pedagogical objectives. The kind of teaching required would not only lead to the appropriation of particular voices in a debate but also the "appropriation" of the dialogical space of the debate. Such teaching would need to combine the construction of knowledge with the de-construction of knowledge. Greeno (Chapter 3) points out what he sees as a missed opportunity in the activities, to explore the affordances of different ways of using graphs: in other words to promote awareness of the field of possibilities at the same time as teaching a particular use. It would also be possible, adopting a community of inquiry approach, to explore exactly what is gained and what is lost when a piece of white paper is divided up by a grid and so turned into "graph paper." The aim of this approach to teaching would be to maintain a relation between the foreground figures that are being taught and the background field of possibilities from which they emerge.

Wertsch and Kazak's account of education as domestication of the imaginations of children may well reflect aspects of the current reality of education but it should not be used to define the limits of education. Dialogic theory suggests that a different approach to education is possible, an approach through which the taking of multiple perspectives can be encouraged and valued. All representations can be taught as moments in an ongoing dialogue or as provisional possibilities in a field of potential meaning. Through this kind of teaching dialogue would emerge as not only a means to achieving shared knowledge, but, more importantly, as an end in itself.

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Chapter 13
Vygotsky and Teacher Education in the Knowledge Age

Sharon Derry

I would like to comment on the chapter by Wertsch and Kazak (Chapter 9, this volume) as a teacher educator sees it, both from the perspective of asking what their analysis of the Lehrer/Schauble video case implies for the preparation of teachers and of exploring how the video they analyze might be used to enhance teacher learning.

Summary of the Wertsch-Kazak Analysis

The most important implication of their analysis is this: Students can harness and use a sign system (e.g., the concepts and tools of basic statistics) without understanding it fully, including participation in a discourse that is mediated by that system. This very idea is what makes instruction possible: A sign system shared at different levels of understanding between teachers and students provides common ground that teachers can leverage to help bring about more sophisticated understandings. Through dialog among teacher-experts and student-novices, lower levels of intersubjectivity gradually grow into more sophisticated forms of mutual understanding, which pushes student development. Because expert-novice dialog presses students' undeveloped thinking into culturally-determined structural forms, Wertsch and Kazak employ the metaphor of "taming" (p. 155) to capture the essence of what instruction is about.

Wertsch and Kazak argue that their analysis has important implications for assessment in the following sense: Because students can use words that are part of a higher-level discourse, and because more knowledgeable others respond with a higher level of understanding than a student may hold, it is often very difficult to determine through observation whether a student has actually mastered a term or other semiotic means and is truly fluent with the discourse. The authors claim

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it is easy to tell if a word is used inappropriately, but difficult to know if students fully understand as an expert would. The authors thus suggest that teachers and researchers examine interactions in detail and take a conservative approach, always assuming the lowest possible understanding and basing instructional decisions on that principle.

Wertsch and Kazak provide two illustrations of how their analysis provides a lens for viewing the subject video. They begin with a segment early in Excerpt 1 (Appendix B), showing the nature of the goal-directed activity in which students are participating, which is somewhat vague: students are told their goal is to organize their data to help them find a *typical* plant (previously cultivated in an experiment) and to determine how the plants vary from one another. The authors then discuss two examples illustrating how cultural tools (graph paper, statistical concepts) allow groups to enter into intramental functioning although different parties understand the task at very different levels. One example is from Excerpt 4, used to illustrate how graph paper is leveraged by the researcher/instructor (LS) as a semiotic means enabling her to establish lower levels of intersubjectivity and help move a small student group to a more expert level. In this excerpt LS tries indirect forms of scaffolding, but ultimately resorts to direct explanation (direct other-regulation). In the end, as Wertsch and Kazak argue, one cannot ascertain how much students actually know, but they seem to be operating on a higher level of intersubjectivity with LS. A second example based on Excerpt 5 with a different group and researcher/instructor is employed to illustrate a similar position.

Finally, Wertsch and Kazak consider an alternative constructivist interpretation of the excerpts, arguing for a blended theory of socioculturally situated constructivism. From their viewpoint the students don't construct the tools themselves, but rather socially construct understandings of tools through the process of reaching for higher levels of intersubjectivity during tool use.

The Commentator's Perspective

In some ways, the Wertsch and Kazak viewpoint as just described is consistent with my own approach. As a researcher and teacher educator, I have also characterized teaching and learning as a process of mentoring students in the context of culturally meaningful activity, with the goal of helping them be able to effectively use culturally-relevant semiotic sign systems. In my context this requires teacher-learners to appropriate conceptual ideas from the learning sciences and use them to reason about their professional practice. In the context of the Wisconsin Fast Plants® curriculum that is the subject of this book, this requires middle schoolers to appropriate tools such as graph paper and concepts such as distribution, central tendency, and variability, and to use them to design inscriptions. Based on my experiences I will argue that such mentoring in the context of authentic activity is a very challenging form of pedagogy. My commentary will address why this type of pedagogy is so difficult. And like other commentators in this section taking a dialogic perspective, I will also challenge the Wertsch and Kazak analysis in certain ways.

I will question whether this perspective, developed within a closed society during the industrial age, is still appropriate for teacher education in today's "knowledge society" (Bereiter, 2002).

To provide a context for my remarks, I mention some of my own experiences in using video cases for teacher preparation and the study of teacher and student thinking, which include: An examination of Janet Kolodner's Learning By Design^{TM} classroom in which students are mentored to learn physics concepts while designing balloon cars (Leonard, 2006; Leonard & Derry, 2006); work with Cindy Hmelo-Silver on helping pre-service teachers develop useful knowledge of the learning sciences through problem-based learning (PBL) in which teachers analyze and redesign instruction presented in video cases (Derry et al., 2006); and a teacher professional development program in which middle school teachers are mentored to acquire concepts of algebraic reasoning through analyzing and comparing cases of algebraic reasoning (Derry, Wilsman, & Hackbarth, 2007).

As both a researcher and teacher in such settings, I use video clips of classroom practice as objects of inquiry to address and help teachers address these questions:

1. What are the most important goals for education?
2. How should we conceptualize the process of learning?
3. What are the best forms pedagogy, including roles for teachers in these pedagogies?
4. How should learning goals be assessed?

My commentary that follows examines the Wertsch and Kazak analysis and framework in terms of these questions.

The Goals of Education

On the matter of goals Wertsch and Kazak are fairly clear: What students should master in school are important *tools* of the cultures in which they are preparing to participate, which include conceptual artifacts, language, technologies, modes and styles of expressions and the like. By *acquisition of cultural tools* Wertsch and Kazak mean that students should become fluent *users* of complex sign systems, being able to successfully employ them appropriately in a broad range of culturally relevant discourses. Wertsch and Kazak contrast their educational goals with views of education implying that the important goals of schooling are primarily learning *about* tools.

In teacher education settings, I would consider these points in connection with current debates about appropriate goals for education in the twenty-first century "knowledge age" (Bereiter, 2002). In *The Handbook of Educational Psychology*, Bereiter and Scardamalia (2006) contrasted design-oriented versus belief-oriented approaches to education, arguing that the educational process should focus on design-oriented practices. This is related to the Wertsch and Kazak preference for framing goals of education as learning the *use* of tools rather than learning *about* them, but there are important differences in the two analyses.

Bereiter and Scardamalia believe that the primary goal of education today is to build students' expertise in using a particular type of cultural tool – *knowledge* – for a particular purpose – *design*. Knowledge tools exist in the world as *conceptual artifacts* that embody ideas and conceptual systems, such as mathematics. Conceptual artifacts include technologies such as Mathematica®, which epitomize conceptual systems. Although the important work of the knowledge age involves manipulating knowledge, certain trends in schooling today encourage over-reliance on situated practices emphasizing concrete thinking and hands-on activity. Educational activity focusing on situated manipulation of material artifacts rather than manipulation of generalizable abstract symbol systems is deemed by these authors as inadequate preparation for a knowledge-age society.

Bereiter and Scardamalia favor a particular type of design activity in schools: development of new ideas. They believe students' education will produce understandings of cultural tools if students are engaged in explaining conceptual artifacts that the students themselves *design*. This is different from asking students to acquire language and other cultural tools so they can use them primarily to explain and justify already-existing knowledge. This is an important point because in the video case that is the subject of this book, the goal of the curriculum developers appears to be design oriented in precisely the way that Bereiter and Scardamalia mean. Rather than getting students *only* to appropriately use cultural tools, such as statistical concepts and graph paper, the intent of the curriculum developers is also that students use these tools to design their own conceptual representations of plant "spread" and "typicality." That using tools to support creative design is as important as acquiring the consensus view of those tools is supported by the curriculum developers' published explanation of their work (Lehrer & Schauble, 2004):

> We were especially interested in student-invented inscriptions and notations as mediating devices for concepts of distribution consistent with our general research interest in inscription as a foundation for model-based reasoning – especially when students debated the merits of different inscriptions for a common purpose (p. 642).

> But as they measured the heights of individual plants, students discovered that neither the attribute nor its measure were as transparent as they had anticipated. Should the height of the plant include the roots? Suppose the plant leaned. . .After resolving these issues, students recorded heights of plants throughout the life cycle, keeping data in the form of simple records of their own design. We made no effort to impose any particular structure on the measurements (p. 643).

That design was an educational goal is also supported by evidence from the video case being analyzed in this project, including the segments analyzed by Wertsch and Kazak and their commentators. For example, in Excerpt 4 [0:40:15–0:40:35], RL, one of the researcher/teachers, visits a group that has been working independently on developing a "line chart." The majority of RL's turns are clarifying questions and include exchanges authorizing students to make decisions, as illustrated by the following fragment:

Excerpt 5 [0:40:15–0:40:36]

```
0:40:15 RL:        = Oh you're gonna hav:e, um so you're gonna
                   have sixty three ⌈different (0.5)
                   ⌈plants: here. =
0:40:18 RL:                         ⌊((pushing finger along
                   y-axis))
0:40:19 Jewel:     ⌊Plants.
0:40:20 (Jewel):   = Yeah. =
0:40:20 Anneke:    = Does it matter? With tha- (things are).
                   You're trying to figure out those: (.) tha:
                   two answers. And it doesn't matter what tha
                   names of forty-six. the plants are: in those.
                   So couldn't you just put (.) data from (.)
                   like Day Nineteen? Couldn't you do that? =
0:40:35 Jewel:     = You hafta ⌈organize your data.
0:40:35 RL:                    ⌊Sure, you can do anything
                   ⌈you want (           )
```

Yet Packer (Chapter 10) sees this excerpt and others very differently, interpreting them as illustrations of how instructional authority shuts down students' agency, enthusiasm, and creativity. Moreover, he faults the Wertsch and Kazak analysis, not so much on its capacity to explain the classroom interaction, but on its failure to provide suitable guidance for twenty-first century pedagogy. Wegerif (Chapter 12) is more sympathetic to the instructor/researchers, but his argument has similar overtones. He sees dialogue itself as the important instructional goal and discusses the failure of the Wertsch and Kazak analysis (and the monologic Vygotsky-Shpet approach in general) to supply an appropriate framework for pedagogy. I refer readers to their chapters for full explanations of these viewpoints.

How can we reconcile that widely varying views regarding goals for students are gleaned from the same instructional case? On the one hand, and in accordance with the Wertsch and Kazak analysis, the teachers and researchers appear to be guiding students toward *culturally-appropriate* tool use. On the other hand, students are expected to use knowledge in creative ways to design their own forms of representation, which does not accord with the Wertsch and Kazak view. I say it does not accord because Wertsch and Kazak explicitly claim that students are expected to understand but not invent cultural tools. They are largely agnostic about what types of tools and activities should be included in the cultural induction of students, but perhaps unintentionally, they proscribe those involving creative invention of knowledge.

One reason for such disagreement is that the video case has been *selectively* analyzed to support different researchers' favorite viewpoints and theories, and these selections may be unrepresentative of the whole picture. My hypothesis about the whole picture is that the researcher/instructors are trying to accomplish multiple goals, which include helping students develop creative agency and ability to participate in public discourses, in addition to acquiring basic cultural tools and ideas that make creativity and participation in discourse possible.

Like all teachers, these are operating within a reality that includes required curricula, state and local standards, assessment programs, and far too little time. For innovators in education, the explicit teaching of cultural tools imposed by these requirements is sometimes part of the Trojan horse that helps move design and dialogue into the classroom. To provide another example, Kolodner's Learning By Design™ project brought engineering design into middle school science classrooms, but it was presented as a vehicle for covering a required physics curriculum. However, the engineering projects were not easily modeled with the required science concepts, so teachers sometimes interrupted design activities to provide direct instruction (lectures) to emphasize the science content in the students' design work. Wertsch and Kazak would view this as resorting to a form of direct regulation, and it is a tradeoff that occurs because of a tension between the need to help students efficiently acquire cultural tools (science ideas such as force and friction; statistical ideas such as variability and distribution), and the curriculum developers' and teachers' desires to foster students' creativity and capacity for self-directed learning. This is the universal tradeoff that Wittgenstein had in mind when considering the aphorism: words are the chains that set us free (as cited in Pea & Lemke, 2007). Such tensions and tradeoffs are ubiquitous in classrooms, and I believe that analyzing a *representative* sample of the Lehrer and Schauble video (rather than episodes selected to illustrate a point) would be valuable in helping us uncover the range of tensions that arise in this instructional case and how they are resolved, helping us better understand what balances are struck by teachers of culturally-situated curricula that also value goals of creativity and design. Are these tradeoffs mostly dialogic versus monologic in nature, as Wegerif's analysis emphasizes? Or should they be conceptualized as authority versus student agency, as both Packer and Wegerif might agree. Perhaps many should be framed as compromises between what is desirable versus what is possible to accomplish in a limited time span. In Lehrer and Schauble's introductory chapter, Schauble describes such a tradeoff reasoning in Excerpt 4, as she makes a decision to "push" one group toward a particular type of data representation that she felt the entire classroom should experience. The tradeoffs that must be negotiated *in situ* in order to meet constraints of time and other resources should, themselves, be understood as distributions within episodes over time.

The Learning Process

Wertsch and Kazak describe the *process* of learning as a dialectic "struggle" (p. 212) between the learners' thoughts – which are amorphous, unstable, flowing – and the sign systems they are supposed to appropriate, which serve to tame and conform students' thinking to particular cultural forms. The authors draw an interesting connection between this dialectic and *distributed cognition* (Hutchins, 1995), because the sign systems that students appropriate may communicate to knowledgeable others more capability than students actually possess. It is the active struggle to participate in a discourse using cultural sign systems with more expert others that causes students to gradually construct more complex and useful understandings of these sign systems.

I think it is important for teachers to understand that this struggle is not the purview of young learners alone, but is a general statement about the nature of learning and participation in world. A similar struggle takes place as I craft my argument for this chapter. The students' uncertainty with regard to the task of "organizing their data" is not so different from my own task of preparing a coherent commentary given the position papers, transcript excerpts and other commentaries. In both cases (mine and the students'), we must work out for ourselves what will count as an acceptable solution. This is part of a dispute of Excerpt 12 – some students were questioning whether or not the representation prepared by Rachel and Jenny satisfied the requirements of the assignment. One possible difference between my struggle and that seen in the Lehrer and Schauble classroom relates to a system's intent to impose a particular set of cultural tools upon my work. It is probably assumed that I already know about the tools of my culture (e.g., a word processor, the concepts within my disciplinary communities), and I am supposed to use them appropriately to design a conceptual artifact – this chapter. By contrast, students have more thoughts that must, from the Wertsch and Kazak perspective, be "tamed" by the educational experience. Presumably there is no such instructional taming agenda for me.

But let's examine this contrast. The circumstances of this book project, my editors, and the "rules" of the community within which I operate *do* shape this chapter to meet criteria. Officially there is no consensus that forces me to understand things in a certain way and write certain ideas. Rather than saying something standard, I am probably expected to spout something unusual and clever. But it cannot be too unusual or too clever, it might not get published! I am designing, but my struggle involves learning and fitting in. The students in the Lehrer and Schauble classroom are struggling to learn how to fit what their teachers want, but they are clearly designing and inventing ideas. So if the differences in our activities are largely matter of degree, not substance, then the Wertsch and Kazak analysis of this video does have validity. And its value for teacher education is largely in its power to help educators "see" how activity, both within and outside the classroom, represents being tamed by authority, either explicitly and visibly or implicitly and covertly. But still the question arises of how the teacher can play this role without over-constraining the students' autonomy and creativity in design.

Because this "taming" aspect of the Wertsch and Kazak analysis is challenged by other commentators in this section, and at the risk of very seriously oversimplifying their elegant and complex arguments, I briefly point to what I see as major contrasts between the Wertsch and Kazak perspective on learning and those of Wegerif and Packer. First, Wegerif's re-interpretation of the video excerpts takes the focus off mediating cultural tools, placing much stronger emphasis on dialogic (as opposed to dialectic) processes, including interpersonal processes and the importance of taking on others' points of view. He moves us from a socioculturally-understood monological perspective to a more inclusive dialogical one. Second, both Wegerif and Packer are concerned about authoritative positioning that a curriculum imposing culturally-determined sign systems and external regulation of students' learning implies. Packer in particular sees the Wertsch and Kazak analysis as over-emphasizing the authority of the teacher and illustrates how this authority is exercised in the video in ways that appear to decrease students' desire to participate. From Packer's perspective, learning in the classroom should result from empowering students as creative, self-regulated constructors of their own knowledge. These authors see the choices for the teacher as dialog versus monolog or as agency versus non-agency.

These arguments about learning, which are also arguments about educational goals, imply that students might be guided to learn in many different ways, but that less constraining ways are considerably better than others. I believe such debates are important for teachers to consider, and they are also important for teacher educators. I know from experience that theoretical debates are also very confusing and frustrating for teachers if they do not lead to practical knowledge. The Wertsch and Kazak viewpoint is appealing because it is easy to understand and seemingly useful; their chapter is accessible for teachers. One can debate the extent to which cultural tools should be imposed, but the concepts presented by Wertsch and Kazak provide suitable language for capturing this debate. I doubt that most teachers would patiently digest the complex theoretical arguments offered by Packer and Wegerif, although I think they are important and would eagerly assign them to graduate students. One challenge for me as the teacher educator is how to take what is learned from projects such as this and effectively translate it into teacher professional development. The nature of this very project implies that one should take a dialogic perspective in supporting teachers' learning about the theories that explain the video case, but doing that is challenging and requires tradeoffs. There remains Wittgenstein's universal tension, between imposing the rich cultural history reflected in the words of this book – words like sociocultural, constructivism, dialogue – versus allowing teachers to construct rich interpretations based on their own practices and experiences and knowledge.

Pedagogy

Inherent in Wertsch and Kazak's position is the idea that good pedagogy is that which helps students acquire appropriate use of cultural tools. But beyond this idea, the current analysis is relatively silent on pedagogical design, although it brings along the full complement of ideas about pedagogy that have come to be associated with the Vygotskian tradition. Because the Wertsch and Kazak analysis is incomplete in this regard, it is useful to consider what other resources are available to teacher educators who wish to use the Lehrer and Schauble video case as a mediating tool for developing teachers' pedagogical practices.

That both Wertsch and Kazak, as well as Packer, draw connections between the Vygotsky-Shpet perspective and constructivist pedagogy suggests that teachers can build on an idea that is familiar to them – constructivism. However, this concept is often understood in limited ways, not as a theory of learning, but as a pedagogical process of promoting engaged learning through "hands-on" activities with concrete tools. Teachers at all levels would likely know that constructivist pedagogy entails helping students build new knowledge on their prior conceptions, taking into consideration possible misconceptions that might hinder students' understanding, as well as what naïve ideas students might hold that could be activated to help them learn. However, even experienced teachers would likely have weak mastery of these ideas as judged by the Wertsch and Kazak criterion – appropriate use in varied classroom contexts.

In addition to knowing about constructivist pedagogy, teachers at all levels would have encountered Vygotsky 101 and could be expected to recall that this sociocultural pedagogy involves engaging students in developmentally appropriate activities that afford the acquisition of cultural tools. They would likely believe that a Vygotskian approach means creating a learning community in the classroom, in which the teacher serves as a fellow problem solver and mentor, studying and scaffolding students' performance and gradually increasing the level of expected performance for each student, moving all students to higher levels of mental functioning. However, although teachers would "know about" sociocultural concepts in addition to constructivist ones, they would probably not have a very deep knowledge in terms of being capable of effectively using these ideas in classrooms. In fact, attempts to put these ideas to work in teaching might even have convinced teachers that although these theoretical ideas sound great, they are impractical in practice, especially in today's No-Child-Left-Behind political schools culture that judges teachers and schools on students' standardized test scores.

The video case and supplementary readings, including the Wertsch and Kazak analysis, could be useful tools for helping to raise teachers' understanding and level of acceptance of these idea systems and their ability to use them as tools for teaching. These materials might help teachers "see" how these ideas could be put to work in an actual classroom. Classroom video in particular can help engender perceptual knowledge that is similar to that gained during actual teaching experience (E. J. Gibson, 1969; J. J. Gibson, 1979), helping classroom-based teacher education move closer in important ways to practice-based professional development, which is widely advocated (Derry, Hmelo-Silver, Nagarajan, Chernobilsky, & Beitzel, 2006; West & Staub, 2003). However, there is a cautionary tale to tell, and it has several themes. One theme, unfortunately, is intolerance. American teachers, both pre- and in-service teachers (as well as researchers, I might add), tend to be critical rather than dispassionately analytical when judging instructional video. This is confirmed not only by my personal experience as a teacher educator but also by the research of Kevin Miller (2007), who suggests that the tendency in American culture is to judge the quality of teaching very quickly on the basis of surface and personality features and unrepresentative samples of work. Another theme is about unrealistic expectations. Some teachers are idealists who, after finally "coming over" by embracing a synthesis of constructivism and Vygotsky as their teaching philosophy, will tolerate nothing less than an untainted and flawless implementation of it (even though they may have little knowledge or experience themselves in working with it or judging actual classroom teaching situations). Unfortunately, untainted, flawless implementation is not to be found in the real world, or even in carefully selected and edited video cases of real classroom teaching, much less representative ones.

Progressive teaching is a complex, reflective balancing act involving tradeoffs, as illustrated in Excerpt 4 when researcher-mentor LS, working with a small group of students who were floundering on their own, guides them gently but explicitly through the process of creating a histogram. Many researchers and teachers who view these videos tend to be critical of this kind of direct instruction. But as Schwartz and Bransford (1998) have persuasively argued, there is a time for telling. To criticize such episodes as a lack of skill, a bad move, a temporary abandonment of constructivism or sociocultural theory or student-pedagogy or whatever, reveals a failure to appreciate the complex, reflective balancing act that is taking place, and may expose the naiveté of the viewer. The nature of this balancing act is illustrated in these words of the curriculum developers, whose teaching was captured on the subject video:

> Students designed displays of the heights of a collection of Wisconsin Fast Plants® at a single day of growth. The intention was to work from what students could readily see – differences in height – and to stretch this understanding of variation-as-difference into an understanding of variation as structured differences, that is, as distribution. . .As students designed their displays, we encountered both opportunities and obstacles, and these informed our next steps. For example, as they designed their initial displays, most students were oriented toward cases rather than aggregate views of the data. We intervened to ensure that at least some students created displays that showcased aggregates for consideration by the entire class (Lehrer & Schauble, 2004, p. 461).

What the video represents is a complex and challenging form of pedagogy – practices that seem headed in the right direction but not yet fully understood (hence still being researched). Interesting and glorious theoretical ideas in the abstract don't seem so clear-cut and straightforward and triumphant in actual practice. The Wertsch and Kazak claim – that engaged learning is a form of dialectic *struggle* between the amorphous thoughts of students and the cultural forms of expressions they are acquiring, and by extension that teaching itself is a similar struggle involving use of the concepts associated with pedagogical approaches – can serve as an important discussion point for teachers entering into video study.

Tradeoffs are made as well in the educational settings in which this (or any) classroom video case is employed as a tool for teacher training. Prior to viewing and discussing classroom videos, teachers participating in my programs are provided with readings and other assignments that supply all participants with a set of conceptual tools that they are expected to use as a basis for thinking about and discussing the video. We have experimented with this procedure and found that supplying these readings *before* video viewing rather than after increases learner comfort and builds understandings of concepts that they would not acquire otherwise (Beitzel & Derry, 2009).

My experience with teachers' video discussions that follow such assignments reveal that ideas from readings are often used in naïve and superficial ways.

However, even these fragile understandings serve as boundary objects (Star, 1989) that allow us to start a much richer two-way dialogue moving toward *mutual* understanding and progressively higher levels of thinking. This insight provided by the Wertsch and Kazak analysis, that robustness is a fundamental instructional property of cultural sign systems in the sense that they allow interaction with understanding at many different levels, is a nice contribution to teacher education.

Assessment

Wertsch and Kazak suggest that assessments of student learning rely on fine-grained analysis of processes involved in intermental and intramental functioning. However, because the knowledge of the observer may be greater than that of the student, they caution and illustrate that it is often not possible to determine whether a students' use of a tool (for example, using the term *variance* to indicate a statistical concept) carries with it all, part, or none of the meaning that the term implies for the observer. For this reason, Wertsch and Kazak suggest that assessors, implicitly teachers as well as researchers, make conservative assumptions about students' knowledge based on observations of their tool use during activities. This approach would cause teachers to more frequently err on the side of failing to detect understanding that might in fact exist.

This is interesting advice for teachers and it may be essentially correct. However, there are several considerations I would like to raise. First, practicing teachers who work every day with 100 or more students would likely believe that continually conducting fine-grained analyses of every student's intermental and intramental functioning is not a practical idea. Teacher education programs nevertheless can help teachers develop systems and strategies for classroom assessment that approximate this approach. Such strategies combine various assessment approaches, including interviews, study of student artifacts (e.g., work systematically collected in portfolios), informal assessment through questioning and observation of students during group work, and traditional forms of assessment that supplement other data. Video that captures student performance during group work or in interviews and that affords more intensive analyses, might eventually come to play a more important role in classroom assessments by teachers, since analyzing such video has already become a part of many teacher professional development programs (e.g., Sherin, 2007).

An example of a systematic assessment procedure is one that Cindy Hmelo-Silver and I have used with pre-service teachers enrolled in our learning sciences courses at Rutgers and UW-Madison (Derry et al., 2005). Our system is based on concepts-in-use rubrics that supply explicit rules for rating the level of teacher-learner's sophistication with respect to how well they use major course concepts, such as *transfer, metacognition*, and *understanding*, in their lesson plans, written analyses of video cases, online discourse, etc. By rating teacher-learners' use of these ideas over time and in various contexts, we can develop a good sense of students' ability to use these tools to think about and analyze teaching and learning.

Ongoing assessment of students requires a sophisticated and flexible knowledge of the subject domains that teachers teach, for such knowledge makes it possible for teachers to analyze, understand, and support a wide range of possible student performances. In general, however, this level of analysis of student work is difficult to achieve in practice because it requires intellectual performance from teachers that many are not prepared to meet. For example, many middle school mathematics curriculums (Connected Mathematics, Math Thematics, Maths in Context) encourage children to become flexible problem solvers, capable of framing problems in different ways, using various strategies and forms or representation, inventing inscriptions, and explaining and evaluating alternative approaches. The teachers' role in guiding these mathematics conversations is essential. However, grades 5 through 7 teachers predominantly have elementary teaching certifications with a minimum of coursework in mathematics. With limited mathematics knowledge, teachers are finding themselves teaching more sophisticated curriculums that require deep understanding of mathematics. The assessment strategy suggested by Wertsch and Kazak is one that requires the capability to see and evaluate a wide range of student performances, requiring a level of sophistication that many teachers don't possess. This problem was not evident in the video because the instructional team being videotaped possessed sophisticated understanding of both student learning and statistics. But this is not necessarily the norm.

The assessment difficulties created by this situation are of two kinds. It is often the case, and for the reasons that Wertsch and Kazak point out, that teachers overestimate their students' abilities. The other situation that occurs more often in my experience is that teachers fail to recognize and build on, or perhaps even discourage, valid problem-solving approaches that are different from the teacher's. A case in point is based on findings from an assessment that we regularly administer in one of our programs of teacher professional development for middle school teachers of mathematics. At the beginning of the course teachers are unable to detect good, conceptually accurate algebraic reasoning for students who use strategies other than traditional algebra formulas to solve problems (Derry et al., 2007). This finding suggests that Wertsch and Kazak's suggestions about assessment, although interesting and conceptually sound, may have limited applicability in instructional practice.

Concluding Comments

Most debates about education are essentially disagreements about the most appropriate goals for learning. My commentary on the Wertsch and Kazak analysis of the Lehrer and Schauble video case relates to such debates. At a fundamental level I do not question their description of the processes underlying learning, their vision of pedagogy and the teachers' role within it, or their ideas about assessment. However, like other commentators, I take issue with the Vygotsky-Shpet position in terms of the way it frames the purpose of education – to help students acquire appropriate uses of cultural tools. I believe this to be part of the purpose, but not the sole one. And I believe an expanded purpose is made necessary by changes in society.

The Vygotsky-Shpet analysis was developed to guide education during the industrial age and within a society in which both work and what was meant by "appropriate usage of cultural tools" was highly scripted. This analysis cannot be transferred without adaptation into American society to guide twenty-first century education. Appropriate goals for learning in "the knowledge age" involves using knowledge as a tool to design new tools and artifacts, including new knowledge (Bereiter & Scardamalia, 2006; Collins, Brown, & Newman, 1989). Bereiter and Scardamalia (2006) argue that in good design-based curricula, the acquisition of cultural tools occurs largely as a by-product of learning to design.

Of course one can argue that before students can design, they must acquire cultural tools enabling design, so the Vygotsky-Shpet analysis still holds. One can argue that apprenticeship and scaffolding and assessment all take place in the context of design, so the Vygotsky-Shpet analysis still holds. However, when the purpose of education is to help students use knowledge in the service of creation and design, the sole emphasis is not placed on acquisition of cultural tools as a prerequisite for that design. Moreover, at least theoretically, students' designs are not always judged in terms of whether they ultimately match canonical or consensus models. Rather, students are encouraged to create designs that they can understand, justify and explain.

Emphasizing this focus is more than a semantic quibble, because it sheds new light on interpreting the video. Based on my own viewing and the curriculum developers' published accounts (Lehrer, Giles, & Schauble, 2002; Lehrer & Schauble, 2004), I would hypothesize that the instruction in the video focuses both on design and acquisition of cultural tools. The assignment to students is to develop their own methods and artifacts to share. They are asked to organize the data in a way that will show what a typical plant is and to provide a view of how the plants are "spread out." They are given a cultural tool (graph paper), but are not scripted on how to use it. They are not necessarily expected to invent the canonical concepts of variance, mean or mode (although some do, more or less). They are invited to discover, invent, think, design, explain, and ultimately evaluate alternative designs. Even though one instructor (LS) moves into a direct mode of instruction at a certain point, my analysis is that she was less interested in dictating an appropriate use for graph paper than she was engaged in complex tradeoffs, trying to get to an instructional "sweet spot" in which she simultaneously "tamed" an unproductive and somewhat unruly group of students while pushing a specific approach that she also wanted to share with the entire class (as described in the introductory Chapter 2 by Schauble and Lehrer, this volume). All of the instructors in the video ask questions that seem designed to get students to think and own problems to the extent possible, not arrive at particular solutions.

Of course many students do wind up constructing artifacts that look a lot like how our culture usually uses graph paper and that represent conceptual ideas that closely resemble statistical concepts like mean, mode, and variability. And perhaps in what can be described as their taming modes, instructors do select and emphasize for discussion certain student creations more than others, moving students toward popular understandings of these ideas. And yet creative, new approaches are wanted from students and, in this type of pedagogy, would be valued and evaluated rather than rejected. This represents appropriation of cultural tools, but only if we define our culture as one that values creative use of knowledge to solve problems that do not have previously-determined answers.

Students in such curricula do indeed seem to carry on a dialectic struggle involving mapping their amorphous, fluid thoughts onto. . .what? I would argue they are mapping their thoughts onto their designs – using those thoughts and constantly constructing new ones to model, explain, understand, designs that work *for them*. It is the creation and discussion of artifacts that helps develop ideas into useful tools for future design work. If in the process of doing this they seem to flounder along the way, additional cultural tools are introduced to help them along.

The direct instruction episode of LS, where she introduces a particular approach to graphing, itself represents a kind of dialectic struggle for the teacher – one of resolving tradeoffs between helping students use their own knowledge to design versus providing them with useful conceptual artifacts and guidance. This classroom represents a highly challenging form of pedagogy in which good teachers are constantly steering between the Scylla of overly direct regulation on the one hand and the Charybdis of "minimally guided instruction" (Kirschner, Sweller, & Clark, 2006) on the other. Even within the most radical of design-based constructivist curricula, a balance is struck between enabling students as self-directed designers and users of knowledge, versus helping them acquire the cultural tools they need to complete their activities (Leonard & Derry, 2006).

An episode of direct instruction (or any single pedagogical move) does not in itself constitute an overall teaching style or pedagogical approach. Yet research shows that American scholars and teachers in particular tend to be quickly evaluative and conclusive when viewing even a small snippet of classroom interaction (Miller, 2007). Because the general human tendency is to view salient episodes as representative of a larger picture, I believe it is important in teacher education to construct classroom cases, including video and accompanying resources and reading materials, to help represent a range of classroom interaction that teachers need to see and consider. The case we examined for this book seems an excellent selection from this perspective, especially given the range of excellent materials (this book, the developers' publications, numerous other available interpretive readings suggested as references throughout this book) that now, because of this project, accompany it.

It is also important to guide case discussions to enable reflective and meaningful discussion, which does in my view include providing and guiding the use of culturally-appropriate conceptual tools for thinking deeply about the case. The Wertsch and Kazak analysis provides an important set of cultural tools, and it is very fortunate that their chapter in this volume is readable and accessible and interesting for teachers. In using the case I will further supplement this reading with other materials, such as excerpts from the curriculum developers' own analyses (Lehrer & Schauble, 2004), the Bereiter and Scardamalia (2006) piece advocating design-based approaches, as well as readings that challenge design-based approaches (Kirschner, Sweller, & Clark, 2006). I would provide others' written integrative analyses (e.g., selected chapters in this book). But as facilitator of classroom discussions, I would aim for a balance between "appropriate" use of these interpretive lenses, versus encouraging teachers to use such discussions to creatively view and construct their own interpretations and conceptual artifacts based on these. My ultimate aim is to enable teachers as designers.

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Chapter 14
Responses to the Commentaries

James V. Wertsch and Sibel Kazak

We appreciate the commentaries written by Packer, Sherin, Wegerif, and Derry on our position paper. Each brings different perspectives with thought-provoking ideas about the implications of our analyses and raises some interesting and important questions relevant to theory, teaching, learning, assessment, teacher knowledge and education that will be the focus of our responses.

Response to Packer

Packer has done a thorough and thoughtful job of reviewing our line of reasoning and observations about the classroom interaction. In the end, we probably come down to a disagreement over how to interpret the interaction that went on between teacher and students, especially when it comes to the issue of how processes of decontextualization should be introduced into instruction. In many respects, this does not have so much to do with interpreting what actually transpired in the materials we have analyzed, but what might transpire in a different form of instructional interaction, one that Packer would prefer. Given that our analysis was concerned with the former, in the end we have not addressed some of the issues he has raised.

We would note that we do not see our line of reasoning as precluding creativity on the part of students, teachers, or artifacts. However, we also do not see students and teachers as equally likely to develop a new understanding of graph paper, words, or other artifacts based on what another party is saying. In that sense, Greeno's "preferred representation" (p. 56) is one that is clearly less open to negotiation than the ones often brought to the table by students. To us it remains reasonable to expect that students are more likely to be saying more than they realize than is the case for teachers. Perhaps this is no surprise, given that we approached the transcripts of interaction from the perspective of the development toward what Vygotsky regarded as higher forms of abstraction.

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With regard to the reading of Vygotsky more generally, we have other differences with Packer. In our view Yaroshevsky provides an interpretation of Vygotsky that goes beyond what Vygotsky himself had to say about how his ideas grew out of Marx or the Soviet system. To be sure, Vygotsky did employ the ideas of Marx, but it remains a valid question in our view whether any of Vygotsky's core ideas are *necessarily* Marxian or Marxist. Yaroshevsky emphasized that they were Marxist in origin, but his analysis reflects a particular late Soviet perspective that in our view did not motivate much of what Vygotsky had to say.

Response to Sherin

In his stimulating commentary, Sherin brings out a perspective based on a major theoretical research tradition in science education field. He contrasts the conceptual change perspective with the Vygotsky-Shpet perspective discussed in our chapter in the latter's emphasis on prior knowledge in science learning as well as discusses key insights from both perspectives.

The prevalent assumption amongst the science education community is that students come to the classroom with informal science conceptions grounded in everyday experiences. Accordingly, Sherin points out that to a great extent research on science learning focuses on students' pre-existing knowledge. He further explains that in the conceptual change literature some researchers view such intuitive science knowledge as having to be replaced whereas others emphasize how it needs to be altered. From this perspective Sherin concludes "there is little attention focused on the knowledge that exists as students enter into science instruction" (p. 192) in our analysis, and he argues that the students' pre-existing knowledge needs to be given more consideration. As noted by Sherin, this intuitive knowledge prior to instruction can be related to thought that is characterized as "inchoate" or "amorphous" prior to the mastery of a sign system in our writing. Sherin wrote, "Thus, although 'domestication' might be useful as a broad metaphor, it should not become a license for assuming that 'inchoate' thought knowledge cannot be the focus of scientific study" (p. 193). His criticism focuses on the notion that even if the intuitive science knowledge is considered to be "inchoate," there still should be a way to analyze it to understand its nature and role in science learning. This is consistent with Vygotsky's "everyday concepts," but we don't have adequate information in the transcripts we were working with to assess this prior or undeveloped knowledge. The bigger issue is that it would indeed be good to combine assessments of undeveloped knowledge with the sort of transformative discourse that we examine. Our approach does not contradict analyses of informal knowledge, but it does tend to locate knowledge in the use of sign systems rather than in concepts or other structures that are assumed to be more purely psychological in nature. Our focus on mediation entails a sort of distributed cognition approach, which again, need not contradict claims about undeveloped knowledge, but would probably lead to some differences in interpretation.

We all agree that students might have prior knowledge about certain types of graphs and experience with various representations such as frequency charts. If we look at the initial question posed to the students, the students' task was to organize the plant height data to answer the questions related to the typical height and the spread. They were called upon to distinguish various types of statistical representations and generate the most appropriate one in order to address the question. In this context, the fluency in using the sign systems, such as statistical representations, that we mentioned in our analysis involves the ability to decide the most appropriate representation rather than just being able to make any graph.

Another comment that Sherin makes seems to be in agreement with that. According to him, "The problem is not that the students have no understanding of what a stem-and-leaf diagram is, at least not entirely. Rather, the difficulty seems to stem, at least in part, from the need for students to see that using a stem-and-leaf diagram in this context is a good idea, and to understand how it can be put to use" (p. 196). Our analysis involves a great deal of interpretation, to be sure, and it is only suggestive, but part of our argument is that to see that using a cultural tool or meditational means like a diagram is a good idea is highly related to understanding it. Seeing it as a good idea and understanding are complementary processes in this case.

Sherin's interpretation of our approach as "Wertsch and Kazak's image of learning in which 'inchoate' thought is domesticated through interaction with signs" (p. 196) suggests that we underestimate what students know and how much intersubjective overlap exists between student and instructor. We mentioned in the chapter that one must take a conservative approach when evaluating student response/understanding since it may not be the same as the expert's. Furthermore the challenge for both Sherin and us is to know how to assess knowledge on the part of students and how this knowledge undergoes dynamic transformation in communication. Our claim remains that it is useful to approach the process as one in which knowledge and understanding grow up around using a cultural tool. The process is one of moving from "other-regulation" to "self-regulation" over time, and cultural tools like diagrams serve an essential role in this.

According to Sherin, intuitive notions like "typicality" and "spread-out-ness" that both students and experts possess support the intersubjective overlap. When making inferences based on what we saw in the social discourse, however, we did not see much evidence of students' intuitive notions. If there were a considerable intersubjective overlap between students' understanding of those ideas and what the instructor meant when asking the initial questions about the task, we think students' initial step would be to find a better way to organize the data such that it would show where the majority of the plant heights are (typicality) and how much they spread out (spread-out-ness).

In the end, we have proceeded by harnessing the sort of pragmatic logic that Dewey (1938) discussed in *Logic: The Theory of Inquiry*. We are setting forth a hypothesis about how students come to new understanding of scientific "instruments" (like diagrams) and then using this hypothesis as a guide when sorting through data. The bottom line is not so much whether our analysis is "true" in some final way, but whether our hypothesis is useful in providing new insight into the sorts of social and psychological processes we see in instruction.

Response to Wegerif

Wegerif raises interesting and important questions about dialogism in instructional interaction. Specifically, he points out that our analysis of mediation and the transformation of understanding that emerges around cultural tools presupposes some crucial points about dialogue. Starting with a much-needed discussion of the difference between dialectic and dialogue, Wegerif goes on to identify some of the points our argument presupposes if it is to make sense in the end.

As is the case with Packer's comments, much of the take home message here is that successful learning and instruction will require complex interaction between students and teachers and between students and other students rather than some kind of unidirectional transmission of information. We do not disagree, but we may see different issues that should be given primary emphasis. We continue to see cultural tools and the processes of negotiating meaning around cultural tools as playing essential roles in this process, but there is little doubt that our analytic approach runs the risk of taking the focus away from valid issues of authority and dialogicality such as those raised by Packer and Wegerif.

Response to Derry

Derry's stimulating commentary draws attention to teacher knowledge and teacher education in relation to the focus of this book and our analyses of classroom video excerpts from a Vygotsky-Shpet perspective. It also presents challenges to the application and implications of our approach for the current educational practices.

In terms of the goal of instruction, Derry contrasts the Vygostky-Shpet perspective with the "design-oriented" approaches in education. She argues that the acquisition of cultural tools, i.e., to become fluent users of a sign system, approach from the Vygostky-Shpet perspective needs to be adapted into today's society where "Appropriate goals for learning in 'the knowledge age' involve using knowledge as a tool to design new tools and artifacts, including new knowledge" (p. 235). She also points out that the emphasis on the acquisition of cultural tools neglect "creativity" in design-based learning.

We agree that this is an important issue in instruction. Indeed the ultimate goal of much of instruction is innovation and creativity. However, the goals of a great deal of instruction are constrained by the standardized assessment measures we employ, so to the extent that a teacher is inclined to teach in a way that would help students gain mastery that will be assessed in standard ways, there are limits to what can be expected to be encouraged in the way of creativity. In the traditional instructional approach the problem is still larger because it still seems that helping students master the use of diagrams or other cultural tools in science is based on strong assumptions about what an "appropriate" or correct use of the cultural tool is. And Vygotsky's approach often seems to encourage quite traditional forms of teaching, at least when compared to constructivist approaches grounded in Piagetian ideas.

Nevertheless, there always is a large degree of creativity and innovation that is involved in negotiating things in instructional discourse (cf. Keith Sawyer's (2004) ideas about improvisation in discourse and instruction), so the place to look for innovation might be on the intermental plane rather than as a property that we can assess in the individual. Moreover, for innovation to occur on the part of the individual eventually, that individual's knowledge of cultural tools must be relatively deep and rich. Mechanistic, pro forma uses of diagrams and other cultural tools are not what we are after.

So the task for further research might be to document and foster forms of instructional interaction that will push students even further in deepening their knowledge, and in this connection there are several levels of using a cultural tool before learners fully understand it. In fact, we probably never understand the full potential of a cultural tool to organize and guide inquiry.

In our analysis we mentioned the difficulty in assessing students' understanding through fine grained analysis of learning processes at the intermental and intramental levels. And Derry adds to this the important point that teachers' understanding of the content is important. She also notes that it sometimes appears to be limited in application since the teachers often seem to fail to identify conceptually accurate student reasoning. Thus it is important to note that both teacher's content knowledge and pedagogical knowledge are crucial to assessment in the classroom settings. Specifically, from our perspective what we call content knowledge is often a matter of more and more enriched understanding of the full potential of a cultural tool, and pedagogical knowledge is knowing how to help students along through the levels of intermental functioning to reach higher levels of this understanding.

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Part IV
Transactional Inquiry

Chapter 15
A Transactional Perspective on the Practice-Based Science of Teaching and Learning

William J. Clancey

Introduction

This chapter presents the perspective of "transactional inquiry" for understanding learning. In my understanding, this perspective is not strictly separable from the other two perspectives discussed in this volume – termed *participation/identity theory* and *dialogic theory*. Rather than being an alternative, the ideas have developed together in many researchers' minds, providing mutual support and value. In particular, I study and understand cognition within an activity theory framework, within which the notion of identity is fundamental (Clancey, 1997, 2006; Lave & Wenger, 1991; Wenger, 1998). For the purpose of this book, I have focused on a transactional perspective, stressing Dewey's notion of *inquiry*, which I have found to be useful in many settings, and aiming to bridge biological, cognitive, and social perspectives on learning. I provide an overview of the transactional/inquiry framework (section "A Biological-Cognitive-Social Framework"), an analysis of three aspects of classroom inquiry (perceptual work, playful attitude and purposeful context; section "Aspects of Inquiry: Perceptual Work, Playful Attitude, and Purposeful Context"), and conclude with a proposed program of studies for practice-based science of teaching and learning, including research questions relevant to the classroom we have analyzed in this volume (section "Conclusion").

A Biological-Cognitive-Social Framework

In simple terms, the analysis presented here is a hypothesis, namely that understanding what happens in human behavior, and specifically where and how learning is occurring, is facilitated by considering the biological aspect of cognition.

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More generally, my interest is to use a transactional perspective as an analytic tool to reveal neuropsychological processes (in most respects subconscious) that give cognition its character in different animals and individual people. For example, Damasio (1994) has related emotion to conceptualization in terms of neurobiological processes. I use the term *neuropsychological* to refer to neurobiological processes that cause and constrain the phenomena of perception, categorization, memory, reasoning, and learning traditionally studied by psychologists. A transactional perspective facilitates understanding the structural and temporal nature of neuropsychological processes that affect learning (Clancey [1999] provides many examples). For example, a transactional perspective enables productively investigating humor in the classroom videos (section "Playful Attitude and Humor") by relating neuropsychological and social analyses. This understanding provides a useful perspective for evaluating the quality and effects of the communication between students and teachers in the instructional setting.

In brief, a neuropsychological perspective on learning highlights (at least) the following aspects of cognition:

- *The perceptual-motor system* is not input and output to cognitive processes, but organizes and is organized by conceptualization, in a manner that is always simultaneous (a coupling mechanism), as well a sequential in behavior/experience over time (Dewey's [1938] view of *inquiry*).
- *The affective (self-regulatory) processes* by which emotional experience arises is not merely a reaction to a situation, but is part of the orienting mechanism for sense-making, a kind of pre-conceptual organizer (Bartlett's [1932] view of *remembering*).
- *Structural aspects of conceptual systems* (e.g., closure, islands, splitting vs. joining, verbal vs. visual preferences) surface in a variety of frequently ignored experiences that have been defined away as "not cognitive" or not functional (e.g., slips, humor, dreaming); I call this mechanism *conceptual coordination* (Clancey, 1999).

In this introduction, I intend to present the transactional perspective well enough to uncover and analyze events in the classroom videos. I present some postulates from Dewey and Bentley's (1949) *Knowing and the Known*, plus a diagram from *Situated Cognition* (Clancey, 1997, Chapter 10: "Transactional Experience"). I focus on Dewey's notion of inquiry, viewed as a kind of transaction, which is useful both to describe what is happening in the classroom we are studying and to prescribe a kind of idealized, project-oriented form of inquiry that might improve the students' experience.

Transactional Defined

In common parlance, a transaction involves some form of give and take. Buying something is perhaps paradigmatic: Two players have dual perspectives, one sells, the other buys; yet both give and both receive in the exchange of money and goods or services. In computer software, the paradigmatic example is a financial transaction, such as processing a check at a bank. One account is debited, the other credited; two numbers are adjusted. In these examples, an action involves two parties, both of whom must carry out their parts for the transaction to occur. The emphasis is on objects that the players are exchanging.

Another perspective, more common in psychology, focuses on how the players themselves are changed, as in this definition of transaction (Merriam-Webster, 2002):

> **1 a:** an act, process, or instance of transacting **b:** a communicative action or activity involving two parties or things reciprocally affecting or influencing each other.

The change here, the influence, is *conceptual*, in contrast to exchanging physical possessions. In simple terms, Dewey would characterize the financial/database view as an *inter-action* (an action occurring between two parties, as emphasized by the hyphen). In contrast, a transactional view of purchasing, for example, considers how the personal relation of the seller and buyer have been changed: Is the buyer influenced to buy from this agent again? Adopting the inter-action view alone, analyses for automating web services focus on goods, services, and financial instruments, ignoring how the manner in which the transaction occurs influences the customer's loyalty, and indeed, whether they wish to *identify* as being this provider's customer or whether the seller is now more motivated to cater to this clientele (Clancey, 2005).

Within a classroom setting, an inter-actional perspective focuses on players, materials, and processes as more or less given, and investigates what productive exchanges occur: Do students reveal misconceptions? Do they progressively exhibit better skills? Are problems solved efficiently? These are relevant questions, but a transactional perspective examines differently how understandings and actions are developing within the action and hence shaping each other. The subject matter (note the substance metaphor) is not merely presented, exchanged, digested, and tested, but is (potentially) transformed in the understanding of the teachers, as well as the students. Perhaps more simply, the students are not simply presented with a situation that they must then understand, but their understanding of the situation is transformed during the learning experience itself. That is to say, the situation and understanding co-develop; the causal relation is dynamic, involving simultaneous, not only sequential effects.

Garrison (2001) explains the term: "Thinking about 'situation' transactionally reminds us that environment and organism, or context and actor, are methodological distinctions within a single, unified, and *ever-evolving subject matter*" (p. 288, emphasis added). In our analysis of classrooms, this "methodological" aspect is practical, pertaining to our developing interests and interest-oriented construal of events within the emerging analysis. Similarly, the people whose experiences we are analyzing are making their own practical distinctions about "situations, occurrences, and objects" (Dewey & Bentley, 1949) in their own activity. A simplified notion of interaction would place an object or person *in* an environment called "the situation"; the inter-action or transactional perspective emphasizes that situations are continuously conceived and physically changed by actors *within* their experiences (section "Coupling and Sequential Events" explains this in more detail; see also Burke, 1994, p. 22ff).

Encapsulating the idea of dynamic activity – relating context, objects, and purposes – Dewey offers the very useful term, *inquiry*, which emphasizes that learning is an active, dynamic process of investigating, probing, reformulating, hypothesizing, examining, manipulating, deducing, theorizing, experimenting, and so on:

> Inquiry is the controlled or directed transformation of an indeterminate situation into one that is so determinant in its constituent distinctions and relations as to convert the elements of the original situation into a unified whole. (Dewey, 1938, p. 108)

Note that inquiry is not a particular kind of activity, but for Dewey a fundamental aspect of all experience of organisms (Burke, 1994, p. 113). For people, inquiry has physiological, cognitive, and social aspects, constituting a general theory of how we "counteract disintegrating influences and thereby maintain [ourselves]" (p. 141). Notably, the theory of inquiry does not presuppose the deliberative character of human problem solving, but rather provides "the basis of a constructive account" of "mental states, beliefs, desires, consciousness, [and] cognition" (p. 141). That is, inquiry explains how deliberative problem solving – involving descriptive formulations and inferences – develops and especially its non-deliberative physical, perceptual, and conceptual aspects.

Using the online service example, the transactional perspective suggests viewing the customer's conversation with a travel agent as a process of inquiry. For example, a traveler may be planning a vacation and trying to determine what pleasing destinations are affordable. The character of the *problematic situation* (where to go, when and how?) changes as the traveler discovers concerns or opportunities that arise through availability, timing, enabled activities, and cost. A good travel service focuses not on making reservations, but on planning a well-formed journey by helping the traveler articulate and relate objectives and preferences. Indeed, a problem with today's online tools is that they are designed for a business transaction in the most limited sense, and not for carrying out a collaborative inquiry, through which both producer and consumer would learn and develop a relationship (Clancey, 2005).

Readers of Dewey will recognize the relevance of a travel planning analogy, for Dewey's point about classroom inquiry was that the curriculum was just a map, a tool, not a destination (e.g., see Hall, 1996). As an inventory of organized materials it serves as an *instrument*, promoting conversation in which learning on this and related topics will occur. The ordering and emphasis will depend on the circumstantial dynamics of the classroom. A question of interest is, to what extent is a particular classroom engaged in inquiry like the idealized travel planner I have described? Do teacher and student co-construct the students' goals and interests as they discover together what the course materials afford?[1]

An inquiry itself, my analysis of the classroom represents what interests me today, looking at this material. Reflecting on my own methods, I show in section

"Aspects of Inquiry: Perceptual Work, Playful Attitude, and Purposeful Context" how inquiry might have occurred differently in the classroom we are studying.

Inter-action vs. Transaction

In contrasting inter-action and transaction, Dewey and Bentley (1949) were inspired by 1940s biological studies of the cell: "Manifestly, the subject-matter of behavioral inquiries involves organism and environment objects jointly at every instant of their occurrence, and in every position of space they occupy" (p. 130). They claim that the setting is always inherently "transactionally organic-environmental," so we must beware of the danger of specialized investigations that separate the system into parts to be understood independently, which they list as the mind, the psyche, the person, and the neural center.

Dewey and Bentley emphasize that an inter-actional perspective is based on interacting properties of predetermined (atomic) entities. Thus inter-action concerns how traits interact, giving rise to observed properties, rather than how behaviors are improvised, emergent, and dynamic within a developing situation (affected by the person's manipulative probes and tentative actions):

> [The transaction perspective is] inquiry of a type in which existing descriptions of events are accepted only as tentative and preliminary, so that new descriptions of the aspects and phases of events, whether in widened or narrowed form, may freely be made at any and all stages of the inquiry. (p. 122)

> [Inter-action:] the various objects inquired into enter as if adequately named and known prior to the start of inquiry, so that further procedure concerns what results from the action and reaction of given objects upon one another, rather than from the reorganization of the presumptive objects themselves.... Transaction...proceeds with freedom toward the re-determination and re-naming of the objects comprised in the system. (p. 122)

The subject matter, the "facts," and the perception and conception of context and self interests develop in the activity that is the realization of inquiry:

> Inter-action assumes the organism and its environmental objects to be present as substantially separate existences or forms of existence, prior to their entry into joint investigation.... (p. 123)

A transactional approach is wholistic:

> Transaction is the procedure which observes men talking and writing, with their word-behaviors and other representational activities connected with their thing-perceivings and manipulations, and which permits a full treatment, descriptive and functional, of the whole process.... (p. 123)

One should avoid the misconception that some human experiences are interactions and others are transactions. Rather, we are invited to view all human experience as transactional, and like any analytic framework, use it as a tool for inquiry. Specifically, where does it lead in developing a practice-based study of learning and education?

One heuristic for adopting the transaction perspective in the present classroom video analysis is to focus on conceptualizations that are not about objects or people in isolation. After becoming familiar with the players, the layout, and the process, we can consider: *Relations* between people, how they are conceiving of their *persona-activity* (who are they being now?), and *norms* they express and enforce. To bring out the neuropsychological aspect of these conceptualizations, I focus on the interplay of perception, emotion, and conception visible in the classroom video (section “Aspects of Inquiry: Perceptual Work, Playful Attitude, and Purposeful Context”).

Coupling and Sequential Events

The transactional perspective can be useful for talking about and visualizing the relations between emotion, perception, conception, and action as we study classroom episodes. In particular, my approach to situated cognition has been to emphasize how these aspects of cognition are co-determined (i.e., functionally and physically develop together). The main ideas are summarized here (see Clancey, 1997 for elaboration and references):

- Categorization occurs on two levels of neural organization: perceptual and conceptual.
- Conceptual categorization is higher-order (composed of other categorizations hierarchically and serially) and always temporal (either sequential or simultaneous, aka *structural coupling*).
- Categorizations are constructed (develop) from previous categorizations; thus categorizing is in some respects an activation process.
- Perceptual categorizations relate features, which are themselves not given, but learned.
- Information is not given (substance entering the organism, an input), but categorizations forming within actions.
- Perception, conception, emotion, and action are mutually constraining, i.e., they arise together, co-develop, determine each other.
- Conceptualization of context (my situation now) and activity (what I am doing now) are mutually constraining.
- “Seeing as” and figure/ground transformations are fundamental to visual conceptualization.
- Describing occurs in conscious (speaking, writing, silent speech) behavior, not internally as (timeless, subconscious) inferences between actions.
- Descriptions (most generally, models of the world) are instruments within an inquiry activity.
- Descriptions do not act on descriptions in the human brain, in the manner of a logic calculus; descriptions are perceived, reconceived (interpreted), and reformulated through new conceptions – the activity of comprehension is not text manipulation but conceptual re-coordination.

- Deliberating is an inherently conscious activity occurring within inquiry, as sequences of representing (in imagination or the shared world) and reflective comprehension and reconsideration – not occurring subconsciously between thoughts.

Summarizing from Dewey's perspective, thoughts provide the materials for inquiry, they are neither its atomic elements nor its molecular products: "Perceptual and conceptual materials are instituted in functional correlativity with each other, in such a manner that the former locates and describes the problem while the latter represents a possible method of solution" (Dewey, 1938, p. 111). The reciprocal relation of perception and conception develops within and influences inquiry:

> Both are determinations in and by inquiry of the original problematic situation whose pervasive quality controls their institution and their contents. . . As distinctions they represent logical divisions of labor. . . The idea or meaning when developed in discourse directs the activities which, when executed, provide needed evidential material. (p. 111–112)

In my understanding of inquiry, I have also reformulated Schön's (1979, 1987) analysis, itself adapted from Dewey, to fit terminology more commonly used in cognitive science. I believe this framework is a practical starting point for applying a transactional perspective in the classroom, which is to say, to study learning as inquiry:

> Schön's framework requires a shift in perspective: We view descriptions as *created in conscious behavior* – in imagining, speaking, writing, drawing, not manipulated in a hidden, cognitively impenetrable way inside the brain. In its primary manifestation, human memory is the capacity for automatically composing processes of perceiving and behaving, including creating representations (doing, adapting). In cycles of such behavior, what James called the "secondary" aspect of remembering, we *model* what we have said and done before (framing, history-telling) and engage in a meta-activity of modifying our language, tools, facilities, and social organizations (designing). (Clancey, 1997, p. 217)

I visualize these phases – doing, adapting, framing, history-telling, and designing – as iterative and simultaneous (conceptualizations occurring at the same time and influencing each other). Figure 15.1 shows behavior as cycles of perception-action of two people, with different levels of transactional influences. The key idea is that

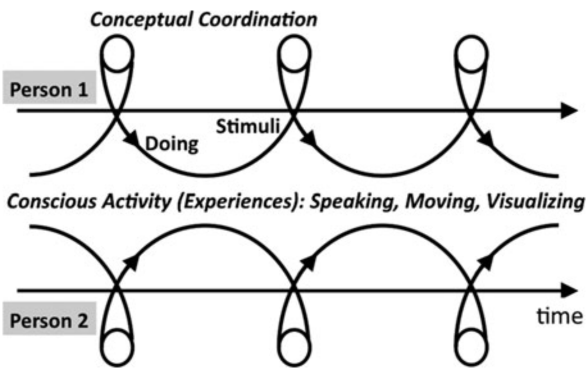


Fig. 15.1 Transaction involving two people

speaking, visualizing, and transforming things in the world occur *over time, as activities,* involving both neuropsychological and interpersonal coordination (Clancey, 1997, pp. 218–219).

The essence of "transactional" is to view stimuli, intent, visualizations, etc. as both reorganizations of experience (present and perhaps distant past) and orientations for the current activity (which involves perhaps simultaneously speaking, drawing, and visualizing). Thus, contrasting with models of problem solving in which a problem is claimed to be given to a subject, the causal relation between problem, inquiry, and resolution is non-linear. Rather than "stimuli causes response" or "emotion is a reaction to a situation" or "conception interprets a perception," we have responses that change stimuli by movement, emotions that orient our conception of what the situation is, and conceptions that change what objects or relations are perceived. In saying "determinants in and by inquiry" Dewey emphasizes that the causal relation is both simultaneous and sequential, represented by the circles and loops in Fig. 15.1. We might look for such temporal relationships in the classroom video.

Nobody contests that learning involves neurological processes; the question is how is the biological nature of learning manifested in a classroom? I show in section "Aspects of Inquiry: Perceptual Work, Playful Attitude, and Purposeful Context" that neuropsychological constraints and influences are especially salient in the perceptual work of creating and interpreting graphs and the humorous interplays of the class sessions we are analyzing.

A Meta-Methodological Reflection

In summary, the essence of a transactional perspective is to beware carving up the world into objects with properties and then studying them alone or in interaction. Accordingly, there is no one way to break up the whole system to define "the transaction." In particular, my own analyses are contingent constructions: I have made selections from the video for a variety of reasons, including the time available to me, what I believe to be of interest to the research community, my past experience in analyzing classroom videos, what engages me today as dramatically interesting, what the camera position reveals, and so on. I have been charged with presenting a particular perspective, so I don't focus on identity, participation, discourse, etc. I am presenting materials that in some important sense do not pre-exist my analysis, in the sense that they are carefully arranged selections; laden with my own emotional manner of ordering my life into a world of objects, people, and relationships; and described in a rhetorical fashion in the genre of a presentation and analysis that must include new findings and recommendations.

It is not my purpose to do a meta-analysis of the methodology of studies of learning, but to present a particular perspective that embodies such a methodology. Dewey states this aptly:[2]

> Selective emphasis, choice, is inevitable whenever reflection occurs. This is not an evil. Deception comes only when the presence and operation of choice is concealed, disguised,

> denied … Whatever enters into choice, determining its need and giving it guidance, an empirical method frankly indicates what it is for; and the fact of choice, with its workings and consequences, an empirical method points out with equal openness. (Dewey, 1958, p. 34)

In particular, I may sometimes appear to be adopting a folk view of research, as I put forward excerpts and interpretations as if they are objective facts that preexisted my interest and are unchanged by my thinking, writing, and working with others on this project. But this apparent unwittingness may itself reflect how neuropsychological constraints affect analytic practice.

Referring back to the logic of inquiry paraphrased from Schön, it appears reasonable to hypothesize that the sequential and compositional nature of categorization affects how we order experience into objectified things, sequential stories, and linear causal models (Clancey, 1999). Were I to self-consciously apply the transactional perspective to critically examine my own analysis as it unfolds, I might stumble over myself, and be ineffective, precisely because as I approach these materials I need to chunk, label, order, sequence, and causally rationalize in a certain way – because that is how the simultaneous, parallel aspects of activity are discretely and serially realized in personal experience, in stories, and in our research communications.[3] Although the initial style is deliberately narrative, we can later adopt a transactional perspective to better understand how the inquiry developed: "Transaction…represents that late level in inquiry in which observation and presentation could be carried on without attribution of the aspects and phases of action to independent self-actors, or to independently inter-acting elements or relations" (Dewey & Bentley, 1949, p. 121).

Further, my reflection on methodology suggests that the transactional perspective may be difficult for the classroom participants to grasp. The ideas of coupling and dynamics may not have any apparent value at first, because they require an understanding of problems and solutions that is not simply packaged into procedures. Teachers may prefer and even require linear causal explanations and methods if they are to gain anything from our study: Here are the parts, here is how you put them together. And at a certain level, this restriction may carry over into the genre of our research writings and workshop presentations.

Aspects of Inquiry: Perceptual Work, Playful Attitude, and Purposeful Context

Before writing the analysis that appears in this section, after several days of reviewing the materials I annotated the two available segments with what I call "Tyler's group" (including Jasmine, Edith, and Kendall). The first is on Day 26, as they design the graph with LS. The second is on Day 28, as they present another group's graph and comment on their own. I then summarized patterns that interested me: Most strikingly, the graphs vary more than I would expect in a classroom exercise. The class converses at some length about the graphs, both with and without teacher direction. The students clearly make sense of the markings, learning why graphs have keys and thus that they may have different designs. The students also explain graphs by attributing beliefs to the designers, recognizing that different groups understand and think in different ways ("To them ours didn't make sense, and to us theirs didn't make sense" [Excerpt 9, 0:09:35]). Contrasted with using conventional textbook designs, the students' graphs provide interesting material for the class to investigate.

On the other hand, based on fidgeting and how often many students appear bored, something appears wrong in how the exercise is designed or being carried out. Further, the teacher's enthusiasm for each graph made me confused about the measure of value; is this a brainstorming exercise where creative variation is highly valued?

With many possible interesting topics to explore, I have chosen to elaborate three themes from a transactional perspective:

1. *Perceptual Work: Putting out representations into shared space.* The graphs are representations that are manipulated, re-perceived, reinterpreted, and adapted in design and presentation activities. But the teacher's virtual modifications of the graphs reveal that imaginary objects may also be shared.
2. *Playful Attitude: What does laughter and play suggest about classroom practice, relevant to designing educational activities and evaluating learning?* The video record enables us to learn a great deal about Tyler's group. Studying the nature of humor in this episode reveals the value of a transactional perspective, specifically in understanding and designing facilitation.
3. *Purposeful Context: The classroom exercise and teacher's lesson plan focuses on math as inherent, abstract properties of graphs, as opposed to framing the graphing within an inquiry about planting.* The confusion about which graph shows "spread" better suggests a problem, which could be explained by the "decontextualization" of the list of numbers (Collins, Brown, & Newman, 1986; Brown, Collins, & Duguid, 1989).

Perceptual Work

Perceptual work is a good example of Dewey's point about the active nature of getting information: Parsing the data chart (called a "graph" in the class), orienting the presentation sheet, understanding graph notation (what's a symbol, what's a design?), relating the graphs to each other. As demonstrated by Schön (1979, 1987) and Bamberger (1991), inquiry often involves constructing representations by perceptually segmenting and manipulating physical objects.

Interpreting Visible Artifacts

The plant data sheet provides an obvious example of perceptual reinterpretation at work. Each word of the title at the top of the sheet is apparently aligned with a

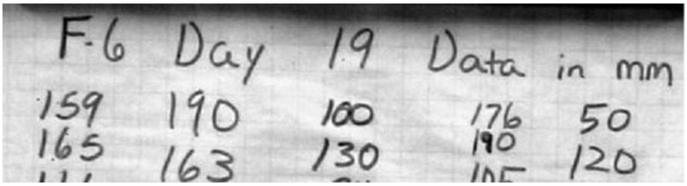


Fig. 15.2 Data chart combining plant heights measured on Day 19 (Excerpt 1)

column: "F-6 Day 19 Data in mm" (Fig. 15.2). The students picked this up. Debbie says, "I don't get it at the top it says F6 and then day and then 19 and then Data (1.0) and then . . ." [Excerpt 1, 0:02:46]. She later re-emphasizes that she is attempting to interpret the first row, "So the numbers under Day are really from F6 and high lighting?" [0:03:16]. At this point, the teacher realizes how she is viewing the table, "Are you thinking these are column headings?" [0:03:27]. This reveals that Debbie is following the convention for perceptually grouping a chart into columns with headers. The teacher segments the diagram by drawing a line straight across the first row, signifying that it is a caption: "It's just F6 and high lights from Day 19 in millimeters" [0:03:31–0:03:39]. He then asks whether Debbie now "understands what she is looking at" [0:03:45].

Another problem is that the 190 below Day might be read as 110 (perhaps explaining Tyler's remark [Excerpt 12, 50:17] that they had one too many 110s). Further, the chart is said to combine data from two experiments, but HL is missing from the title – further implying perhaps that F-6 designates the column with data from that particular experiment. (Indeed, for all we know, this was the original meaning, and later the data were combined.)

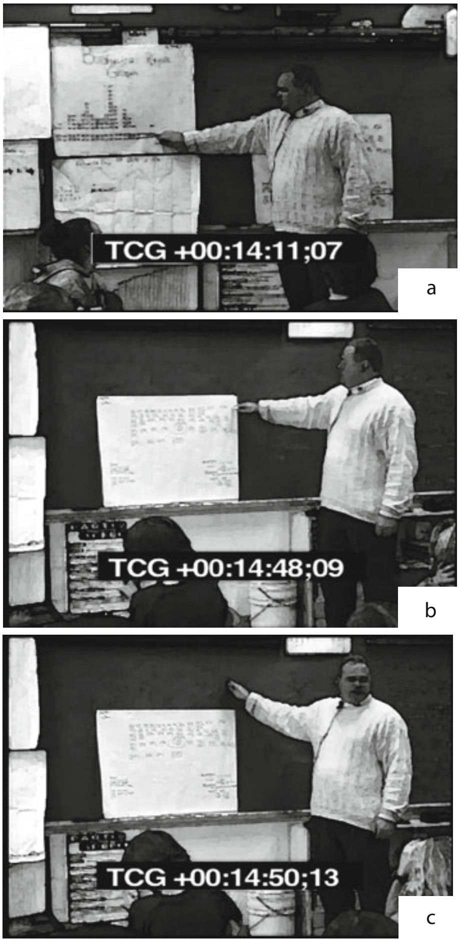
Another recurrent perceptual transformation is how empty space takes on meaning (Schön, 1979). For example, responding to the teacher's question [Excerpt 9, 0:12:26] about whether it is easy to see in a graph a "lot of spread" in the numbers, Kerri notices that using a coordinate system (scale for X-axis on the bins graph) results in white space where there is no data – and this empty space has meaning:

Excerpt 9 [0:12:48–0:13:07]

0:12:48 Kerri: ⌈⌈*((pointing to Group 3's graph shown in Fig. 2.5))*

0:12:48 Kerri: ⌊⌊Well I think that probably this graph because (.) it lea- they still leave: (0.9) some spaces there, (0.8) in case there would be even though there's not, so that you can (.) really see how spread out it is because it (0.5) goes (0.3) thirties, (0.5) up to the most and you can see if when there's like (0.7) >how much< ⌈space is there between it

Another striking example of perceptual work is how physically turning a representational artifact may lead us to interpret it differently. In attempting to explain another group's graph, Ian says [Excerpt 10, 0:18:50] that "they had the tens column going up the side on the Y axis and then they had the ones digit going down the X axis. . .." The teacher responds [0:19:34], "You would like it if the graph was turned maybe," removes the tape attaching the graph to the chalkboard, and re-tapes the sheet to the board after having it rotated it 90°. He says, ". . .it starts to look more like what another group started getting" [0:20:02]. It is a strange idea, when you consider it, that how we conceive a representation depends on how it is oriented with respect to our eyes.



teacher: ... if we have two fifty here, ((*a*))

teacher: Yeah. so we'd have to continue on here to five-hundred and fifty to five-hundred and fifty,
student1: Nine.
student2: Nine
teacher: Ni:ne. ((*b*))

teacher: and then there'd be a five fifty-five right above it. ((*c*))

Fig. 15.3 Imagining how to plot a value of 555. (Excerpt 9)

Sharing Imaginary Representations

In the available video, the most interesting example of imagining representations occurs as the teacher leads the group to compare the graphs and imagine extensions to determine which would “show better the spread” [Excerpt 9, 0:10:28–0:17:03] if they ignored the 255 data point and included instead 555. This is all performed visually, covering the number 255 on a graph and writing 555 on the chalkboard (Fig. 15.3c). He asks [0:10:42] if that “feels like it is quite a bit different,” opening his hands out with arms wide. With no one apparently disagreeing, he asks [0:11:03], “Would this graph help you see that that’s more spread?” Picking up another chart and gesturing, he says [0:11:10], “Let’s say we did it, we did to this one, we put 555 right here on the end.” He points where one might put 555 on yet another graph, and asks [0:11:26], “Is there a graph up there that would be better to help you see that spread?” After a few minutes of interaction with the students, he summarizes [0:13:51] that “having a scale down here, which is 1, 2, 3, whatever it is, would help you see spread better?” He then checks their understanding of this visualization, gesturing how the X axis could be extended from 250 to 555 [0:14:21], with Wally recognizing [0:14:27] that this would require 31 more entries (250 + 10*31 = 560).

Excerpt 9 [0:14:42–0:14:55]

0:14:42	teacher:	Yeah. so we’d have to continue on here to five-hundred and fifty ⌈to five-hundred and fifty,
0:14:44	teacher:	⌊((*extending the x-axis across the board to the right of Group 3’s graph*))
0:14:46	student1:	Nine.
0:14:47	student2:	Nine.
0:14:46	teacher:	Ni:ne and then there’d ⌈be a five fifty-five right above it.
0:14:49	teacher:	⌊((*marking a point on the board directly above the projected x-axis*))
0:14:52	teacher:	>Then that then that< then that would look pretty spread out, wouldn’t it?

Again, they are sketching virtual graphs (e.g., extending out and saying what it would look like). This becomes part of the portfolio of graphs on the board, these imagined extensions. The teacher begins his demonstration (Fig. 15.3a) with the graph designed by Tyler, Edith, Kendall, and Jasmine. He extends the abscissa across the board and eventually onto the tabular representation produced by Janet and Rene (Fig. 15.3b). He then projects a point (Fig. 15.3c) that falls on the board above Janet and Rene’s representation. Once again he asks them to describe this imagined chart, “That would look pretty spread out, wouldn’t it?” [0:14:52].

He continues to ask them to imagine editing the graphs and imagining what they would look like:

Excerpt 9 [0:15:00–0:15:07]

```
0:15:00 teacher:    Whereas on this one, all we'd have to do is,
                    ⌈erase this (0.4) and put a five there (0.3)
                    and we just leave it there right?
0:15:02 teacher:    ⌊((pointing at entry on tabular representation
                    produced by Rene and Janet))
```

He concludes by summarizing the result [0:15:15], "And like Ian said, so long as you have a scale on the bottom, I think that helps people determine how spread something is." Then a 45 s conversation occurs with half a dozen players, as the nature of a scale is further emphasized. More imagined objects and functions are constructed:

Excerpt 9 [0:16:40–0:16:56]

```
0:16:40 teacher:    Yeah, they could put a scale on
0:16:43 teacher:    So five hundred they get to a ⌈hun- (0.3) what
                    do they got up here two fifty?
0:16:44 teacher:                                 ⌊((pointing to
                    top of y-axis of Kurt and Malcolm's graph with
                    a meter stick))
0:16:46 teacher:    So five hundred would be (.) twice as high.
0:16:50 teacher:    So it's gonna be up there somewhere so would
                    that (.) that scale helps you see will help
                    you see how high it is.
```

The students are clearly following along, as Kristen concludes while pointing to Group 3's bins graph and then the Y-axis graph [0:16:57], "I think that one and *that* one would probably help."

In summary, the meaning of the graphs has now been transformed several times: By the groups working with each other to understand the designs; by the presentation with the class probing; and by the teacher's comparing graphs and extending them. They've created a representational world, an ecology of representations, which now includes graphs as artifacts plus imaginary modifications. These are put out by gesturing; they exist now as numbers and lines in a shared space with agreed properties, which are totally imaginary!

The graphs are no longer viewed as just marks on paper, but tacitly as including other (un-written) numbers, and as having a ruler-like scale that defines an axis. The meaning of the graphs for the students now combines their individual intents in their groups as they designed a graph, with the larger issues raised by seeing other approaches and comparing what you can see and what you can change. The overall activity has taken on some of the transactional characteristics highlighted by Schön (1987) in his analysis of architectural sketching, where there is an interplay between preconception of a design, an initial sketch, a reinterpretation of (perhaps serendipitous) markings, and an adaptation of the design to better fit aesthetic and practical constraints.

In considering the notion of fixed, pre-determined objects versus those whose character emerges in activity, we might contrast the teacher's view of concepts like "spread," and the students' – do their own graphs take on new features as they discuss spaces, for example, and how to talk about what is typical (e.g., Tyler's arms in the air, as he shows the middle of the graph)? Here I am reminded of Schön's (1979) analysis of the paintbrush inventors, discovering that spaces between bristles are functionally channels for the flow of paint. Thus something that is perceptually ignored as "blank space" or devoid of content becomes a feature with describable properties, in the case of the graphs revealing a pattern in a group of numbers.

Playful Attitude and Humor

In this section I explore the hypothesis that we can understand humorous activity as transactional, in contrast with the idea that something or someone 'being funny' is a *trait* of a story (joke) or person.

"Reflex" vs. Intentional Humor

My objective here is to illustrate the social aspects of humor in this classroom, and perhaps accordingly enrich our understanding of the experience of learning, especially in a group setting. In particular, I suggest that including humor in a theory of conceptualization will better reveal the functional role of emotion and thus how it should enter into a theory of instructional design.

First, I distinguish between "reflex" laughter (and giggles or smiles) and intentional actions, which are willfully humorous or playful. The latter range from putting on a happy face (Jasmine's smile for LS) to Tyler's gestures in the group, and his flight back into the room. I use the term reflex advisedly, to refer to a response not mediated by inference. Although uncontrolled, it is conceptually organized and not to be confused with non-cognitive nervous system behaviors.[4]

A good example of reflex laughter is when the teacher mispronounces "bin." The teacher says [Excerpt 8, 0:28:52], "You put things into a ben" (he gestures piling from above). A weak voice says, "A bin?" [0:29:03]. The teacher spells it, "Bee eye en." [0:29:05] and two students say, "I thought you said *ben*." [0:29:06]. The class laughs [0:29:07] as he corrects his pronunciation. This is a familiar reaction in a group when someone makes a mistake. The laughter seems to relate both to the conceptual breakdown (the difficulty of recognizing the mispronunciation), as well as the social relation (Provine, 2000; Glenn, 2003). The reaction is quick and subconscious. Overall this laughter suggests a good rapport between the teacher and the class, and affirms a norm for handling slips, which are unintentional mistakes in someone presumed to know better. (It would be absurd to lecture the teacher on the difference between the two words; misunderstanding wasn't the nature of the error.)

Another example of a reflex laugh occurs when a girl has read out the average written on a sheet as a number greater than a million:

Excerpt 8 [0:23:21–0:23:36]

```
0:23:21 teacher:                    ⌊Well even if you divide it
                   think about the number does the number make
                   sense?
0:23:26 teacher:   If we added all these numbers up ⌈would we get
                   a million?
0:23:27 student:                                    ⌊No, if you
                   look carefully it's one hundred thirty-three
                   point seven six nineteen.
0:23:34 Janet:     That's a point?
0:23:35 student:   Yes, it is!
```

The laughter that followed may acknowledge that perhaps the mark is an unusual decimal point, making this a self-deprecating response – a way to handle conflict. Later, a student asks about the origin of the "stair graph" design:

Excerpt 11 [0:30:49–0:30:56]

```
0:30:47 student1:  How how did you get your idea for that? =
0:30:49 Michael:   = Yeah. =
0:30:49 student1:  Cuz I mean it's not something that jus pops
                   into your ⌈(.) head like that
0:30:52 student2:            ⌊Heh: heh heh heh.
```

Several students laugh, possibly reacting to the form of the question. Kerri responds that they "were thinking about different graphs, that we could make like bar graphs and stem and leaf . . .." But they didn't like that, so they just "started to think up new ideas that would work and make it" [0:30:56]. A student replies:

Excerpt 11 [0:31:18–0:31:56]

```
0:31:18 student1:  You wanted it to have like it's an original
                   graph? Because I've never seen that one
                   before.
```

Kerri smiles and laughs, acknowledging the apparent compliment. The interaction punctuated by laughter suggests a certain awkwardness from the uncertainty in knowing how to think about the graph's unusual design. It's interesting, but is it good?

In contrast with reflex laughter, joking and playful behavior occur more deliberately (with attentive control), *as a manner of carrying out an activity*, expressing an attitude that typically persists over several minutes. By the transactional view, a first-order characterization would be that the audience and the humorist co-create the humorous experience or event. Thus Tyler plays to the class, as they anticipate his being funny (and as he anticipates their appreciation). Similarly, the “ben” event starts as a few students’ reaction, but becomes more of a class-wide experience as the students hear each other and the teacher responds.

Considering humor is helpful and revealing because it focuses our analysis on behaviors or even better, *experiences*, as the objects of inquiry, rather than only what we normally view as *things*: groups, individuals, graphs, and terms. We also consider attitudes, revealed in an individual’s tone of voice, gestures, gaze, and participation. Experiences and attitudes are evident in playful behavior when creating the graphs and in their presentation to the class.

Playful Behavior as Mutually Constructed

We find humor in the classroom video in activities and particular actions, often revealing interpersonal relationships: Jasmine and Tyler repeatedly spar in mocking tones; their group jokes around while making the graph; Tyler evokes laughter several times during the group’s presentation. In these activities, the humor involving Tyler suggests a playful attitude. This is most obvious in his group’s graphing activity, but also both he and Jasmine make playful full-body gestures at the front of the room. Tyler, at least, seems aware of himself as being visible. He is “presenting-to” not merely reciting or standing. He doesn’t merely act, he “acts-for” – he conceives of his activity in relation to an audience. His performance is artistic; he improvises aware of his own presence.

This suggests another useful analytic characterization: The participants’ conception of What-I’m-Doing-Now (WIDN, see Clancey, 1999). At times Tyler is evidently showing off, pestering, and flirting. His whistling while LS is speaking to Edith and Jasmine may be interpreted in several ways: He is setting himself apart from “the girls” (LS is helping them; he and Kendall will wait it out); he is also arguably rejecting LS’s intervention and apparent control of the group. But to the point, Tyler expresses himself not by explicitly disagreeing or seizing control himself (LS outranks him greatly), not by going away (possibly not an option), and not by totally ignoring them. While appearing to literally wave LS’s participation away with his sheet of paper [Excerpt 4, 0:30:59], he also interjects relevant remarks, showing that he is paying attention. His whistling therefore appears more like *counterpoint* to LS than drowning her out, a transactional coupling of behavior.

An inter-actional perspective would say, “Ah, Tyler is a playful boy. He is difficult. Place him into any group and he will be the clown.” It may be true that a pattern of sorts will occur, but the *character* of the playfulness, and the manner in which it is disruptive (if at all), is open to change, contingently produced by the actions of the whole assembly. This is why it is helpful to see Tyler during the presentation, where he is obviously engaged and even something of a leader. We see that the class as a whole (apparently) relates to him as humorous (was the teacher smiling?) and he is even self-deprecating.

LS comments in her notes, “The boys do a lot of playing around, especially Tyler, and really need to be pushed to work on the problem.” However, she never admonishes them in the segment available to us. LS is pushing only in the sense of orchestrating the entire graphing process. Was this pushing Tyler away from the table? A transactional view asks how LS’s behavior and Tyler’s were codetermining. Just as we wouldn’t say that Tyler is necessarily requiring guidance, we wouldn’t say that LS is necessarily over-controlling. Together, they form an *ensemble* (with Jasmine, Edith, and Kendall). The ensemble is improvising their parts, as they are inventing a graph, reflecting on the developing design, their progress, their behaviors, and feelings about each other.

Figure 15.1 is an attempt to visualize how two people are mutually constituting their experience. While doing something (even sitting still), each person is perceiving what the other is doing, noticing especially how the other person conceives of what either has said or done before. Some remarks will perhaps be pivotal, but it is difficult to break this into a linear-sequential give and take. Giving and receiving occurs simultaneously for all players, and is multidimensional. Tyler whistles while LS is orchestrating; at the same time he is paying attention to what they are doing while moving around in a way that distracts the others. Oddly enough, when challenged (“Tyler!”) he responds not with something yet more boisterous, but with a productive remark about the work. He is always engaged, as I show below in a more detailed analysis. This conceptual ability to blend multiple activities, being tacitly aware of different threads, allows Tyler and the girls to mix commentary on what is happening, while remaining involved with LS. And thus I stress again that the nature of the activity, as transactional, reflects the neuropsychological nature of conceptualization – a coordination process that is simultaneously compositional (with conceptual blending), sequential, parallel (in creating and relating perceptual features and categories of different modalities), and emotional.

Playing During the Day 26 Design Session

During the design session on Day 26, Jasmine and Edith repeatedly rebuke Tyler with a mixture of smiles and insistence: “Tyler!” “Tyler! Stop it” “Tyler! Get off it” [Excerpt 4, 0:28:21–0:31:23]. Their interventions are short interruptions, which more resemble juggling attention, than shifting context from the work LS is guiding. Tyler is still engaged with them, and their reaction is a means of sustaining this relation, while simultaneously working with LS. The relation is mutual, for Tyler’s noises and gestures are perhaps not deliberate disruptions, but a kind of commentary on the on-going LS-orchestrated activity. Tyler is part of this activity, as indeed the activity for Jasmine and Edith becomes a blend of attending to and relating with both LS and Tyler. Put another way, Tyler’s playfulness is not necessarily a mark of disengagement, but rather *a way of being part of what is going on.* He has not walked away, he is not attending to anything else. He is observing and oriented toward the graph and the conversation with LS. His behavior is a *playful manner* of participation, a mode or style.[5]

Examination of this episode shows that Tyler engages with LS and demonstrates that he is following along. For example, he appears to team up with LS in speaking to the girls when she is momentarily confused, saying that "they don't listen":

Excerpt 4 [0:24:44–0:25:17]

0:24:44	LS:	I'm not making myself very clear, am I?
0:24:45	Jasmine:	Hha ha I don't know what you're talking about actually.
0:24:48	Edith:	But we could, we:=
0:24:49	LS:	Do you get a sense of what I'm talking about, Jasmine?
0:24:50	Edith:	Yeah but
0:24:51	Jasmine:	That's Edith.
0:24:52	LS:	That's Edith ⌈and you're Jasmine?
0:24:53	Tyler:	⌊Say it again (.) maybe ⌈they'll follow
0:24:54	Edith:	⌊Hehehe
0:24:54	Jasmine:	⌊Hehehe
0:24:55	Tyler:	Cuz you know they don't listen. So (.) >say it again.<
0:24:58	LS:	Well I wasn't very clear (.) I was thinkin' (.) we certainly don't have two hundred and twenty five numbers across here (.) but if we said let's use a square and put all the ones that go from say thirty tah:: to fifty or sixty and then: every time we see a number we could put an X above it?

After the girls say they are following LS, Tyler is quick to agree, and Kendall's remark appears to draw him further into the work:

Excerpt 4 [0:25:58–0:26:20]

0:25:58	LS:	⌊Well that's one way of doing it but I don't know if it makes sense to you guys?
0:26:01	Edith:	It makes sense to me:.
0:26:02	Tyler:	Oh I get it!
0:26:04	Tyler:	So yeah yeah what so
0:26:07		((*Theatrically collapses on table*))
0:26:10	Jasmine:	•hhh hahaha
0:26:11	Kendall:	TYLER, okay we have ten:
0:26:13	Tyler:	Like so the ones like (.) you said- you write one through ten?
0:26:18	LS:	Yeah ⌈( ) like that.
0:26:18	Tyler:	⌊Like all the ones one through ten you put Xs for?

After Jasmine rebukes him [0:28:21], Tyler returns the critical tone:

Excerpt 4 [0:28:19–0:28:30]

```
0:28:19 Edith:     Okay we're gonna go=
0:28:20 Tyler:     =Em:::
0:28:21 Jasmine:   Tyler! Stop it.
0:28:22 Tyler:     OH::! You just wrinkled the
0:28:24            ((Pointing finger at Jasmine, Edith snaps
                   playfully at his finger))
0:28:25 Jasmine:   Ha⌈hahahaha heheha
0:28:25 Edith:       ⌊Hahahahaha
```

They are all laughing visibly. Jasmine is obviously happy and looking at Tyler for several seconds. Kendall is pointing and speaking. They are engaged in one activity.

Tyler also picks up the interaction with LS when Edith is uncertain:

Excerpt 4 [0:28:58–0:29:08]

```
0:28:58 LS:        (I believe that's how much there are)
0:29:00 Edith:     I really: don't' understand this.
0:29:02 LS:        Thirty to thirty-nine.
0:29:05 LS:        Forty ⌈to forty-nine.
0:29:05 Tyler:           ⌊Three forty-nine.
0:29:06 LS:        Fifty to ⌈fifty-nine.
0:29:07 Tyler:              ⌊Fifty-nine.
```

But somehow these serious moments are blended with joking around, as for example when he is clearly being "interruptive" when waving the paper, while (perhaps his view of the situation) LS is speaking to the girls. Jasmine is watching with eyes askance (emphasizing her primary engagement with the teacher). Tyler then plays with his arms behind his back and his head near the table, saying "Whoa" and Jasmine tells him to get up:

Excerpt 4 [0:30:56–0:31:24]

```
0:30:56 LS:        Well yeah, so one thing we could do is we
                   could start doing that. ⌈We could right over
                   here and we could try: (0.6) (        ) one
                   thru- zero through nine, ten through nineteen,
                   >twenty through twenty nine,< Just label them
                   across ↑there.
0:30:59 Tyler:                             ⌊((whistling and
                   vigorously fanning a folded paper in LS's
                   direction))
0:31:11 Jasmine:   Shall we start by (tens)?
```

0:31:16 Edith: No:: because people are going to be looking at it (.) this: way
0:31:23 Tyler: Whoa whoa whoa
0:31:23 Jasmine: Tyler! Get off ⌈it.

The eye contact and Tyler's antics suggest that his interest is more in relating to the girls than in pursuing the graphing problem. But Edith too is playful in her tone and emphasis as she draws out her remark:

Excerpt 4 [0:31:48–0:31:55]

0:31:48 Edith: =No::::↑↑ we do:n't wa:nt it tha:t wa:y because we don't want it that way.

Now Jasmine looks at the camera, then rebukes Tyler, and looks at him smiling. Tyler makes a fooling gesture with Kendall, shaking his head up, down, and around very quickly. Tyler also looks up at the camera. Then, referring to the girls, he says, "Wrinklers!" Soon after, they are all laughing when Edith breaks her pencil.

Excerpt 4 [0:32:14–0:32:21]

0:32:14 Kendall: You guys are crinkling the paper! ((*parody voice*))
0:32:16 Tyler: YAH, you're wrinklers!
0:32:18 Edith: Straighter than you guys did.
0:32:20 Tyler: NO:::!

The rebukes are an expression of defining or enforcing a norm, which includes particularly a constraint not to mess with the paper, which is to be the presentation copy. "Tyler!" [0:32:23] could be interpreted as a comment as well as a call, bringing him in to the work. Again, it could have been different: The girls might have ignored him or indeed LS might have said something to stop him. But the expressions and tone suggest more an appreciation of his play than being disturbed. For indeed, controlling propriety and asserting the norms is mutual and playful, as when Tyler says, "OH::! You just wrinkled the [paper]" [0:28:22].

The rebukes – from both sides – constitute the activity of working with LS and preparing a graph for presentation. Again, these remarks seem to be inherent, not interruptions, but a character of the work activity itself. That is to say, this is how they do their work. This is how they carry out the assigned task. *This is their practice*, relating to each other in playful rebukes and interruptions. Indeed, one might say that the proprieties of the classroom, norms such as not wrinkling the paper and attending to LS have provided a resource for relating to each other. This background becomes a setting for Tyler to play against, for them to express how they feel about each other, to explore and develop these emotions. Thus the gestures and drones are figures that tacitly acknowledge the background of the norms. One might analyze further to inquire about the structure of the play, its phases and transitions as people come in and out of activities.

Transactional figure-ground relations – found at all levels of cognitive activity from perception through conceptual classification to interactive style (Clancey, 1999) – seem to be a fundamental organizing aspect of human experience. The formation of categories through figure-ground relations apparently stems from the physical nature of the neural system. In the next subsection, I attempt to relate these analytic perspectives.

Relating the Biological, Cognitive, and Social Perspectives of Humor

In studying the functional aspects of humor, we are confronted with a phenomenon that obviously has biological, cognitive (conceptual), and social aspects. When researchers have studied learning as knowledge acquisition, it has been too easy to omit anything emotional and at the same time a struggle to relate psychological notions of memory and reasoning to social participation and identity. Humor by contrast is unequivocally emotional and often social; certainly the most salient examples of humor – jokes and comedies – involve at least a person and an audience.

On the other hand, although no one questions that humor has a cognitive aspect, the mental processes have not been very well articulated or formalized in models.[6] By Bartlett's (1932) theory of remembering, we might hypothesize that humor is pre-conceptual, a neuropsychological process for conceiving What-I'm-Doing-Now, with aspects that cannot (at first) be coherently related. Functionally, we could say this is the person's means of relating to an incomprehensible situation. In remembering (Clancey, 1999, Chapter 9), the emotional attitude perhaps provides a basis for reconstructing (re-relating) previously active categories, such as in recalling the events of a story. In joking around, the humorous attitude may be a way of coming to terms with events that are inconsistent with past experience and hence otherwise irreconcilable (by the person's normative conceptual logic for organizing activities).

That is to say, in contrast with a folk view that humor is always a *reaction* to a situation (that has the inherent trait of being humorous), humorous experience may be an expression (action) of a disjuncture, a conceptual dis-coordination, an inability to conceive of what the situation is. By Bartlett's analysis, we must experience *something,* we cannot say with blank faces, "Does not compute." Instead, we chuckle, laugh, or giggle. For Tyler, the idea that "we are doing something all the time" is fully visible. (See Clancey, 1997, Chapter 3 for related discussion.)

What I have provided so far is a neuropsychological sketch of humor; the social aspect is of course no less fundamental. Within an interpersonal activity, humor provides a way of handling conflict, which is to say that as each individual must experience something (handle a breakdown in some way), the group also must move its activity forward. So when the teacher asks Janet whether her graph helps one see how spread out the numbers are [Excerpt 12, 0:57:48], she dips her forehead to the table and everyone laughs. As analyst-observers we should always realize: The behavior could have been different. Janet might have said, "I don't know" or "I don't care." Her action instead could be interpreted as a submission, giving in to the teacher's instruction. Her attitude is open, she resolves the tension by playfully presenting she has nothing to say.

When the teacher asks Rene where 300 would be on her graph, and adds "if there was a 300" [0:59:36], everyone laughs. Perhaps something is happening off camera? Or the idea of a plant 300 in. tall is absurd? Or they adopt the teacher's remark as a means of resolving the tension of the moment? I do not mean to suggest that interpreting what is funny necessarily involves a simple, unique causal story. Indeed, an interesting hypothesis is that at first different individuals have different takes on what is occurring at a given moment, but most become caught up in the group's laughing, and *this* shared experience then orients the group's ongoing activity.

Purposeful Context: A Math Activity Within a Plant Experiment?

Seeing Tyler joking and listening to the discussion of "spread out," I often wondered how the students and teachers are conceiving of this classroom activity. I have argued that in the small group Tyler is always in the activity of designing the graph, despite appearing to be only fooling around. But are the students ever in the activity of *doing a plant experiment*? Do they understand that the graphs are tools for conducting a broader inquiry?

Talk About Properties of Graphs

After an hour into the third day, the teacher repeatedly asks questions such as, "Would this graph show you better – just the graph – how spread out it is?" [Excerpt 12, 1:00:42]. This entire discussion seemed boring to me. How can we talk about the quality of the graphs without talking about some issue involving plant growth? In the videos available to us, the described properties of the graphs are treated independently of the meaning of the numbers, which seems bizarre, given that the students actually came up with these numbers by measuring plants.

The numbers were first bastardized when the two experiments were clumped on Day 26. The students appeared puzzled. Now they are just manipulating numbers. The idea of creating and comparing and presenting graphs is great, but then the inquiry has been moved from the plant domain – where graphs might provide value because the numbers *have value* – to the graph domain – a list of numbers and a generalized property called "spread out." In my viewing, the teacher gives the impression that "spread out" is of interest for its own sake, and that tools for talking about "spread out" (the graphs) can be evaluated independently of the domain from which the numbers come.

I hasten to add that the teacher has clearly made the graphs into a tool for inquiry, riffing off the many designs to make larger points about representation. My concern is that this evaluative talk makes no reference to a problematic setting in which charting occurs. There is nothing here about what the graphs are revealing about the plants, aside from periodic mention that the numbers are heights. It is fine to abstractly try out different patterns (indeed, researchers analyzing data may explore charting options in a spreadsheet tool just to see what relations might be revealed). But then you say what you see in the graphs that relates to the phenomenon of interest. What information does the graph provide about plants growing under different conditions or different kinds of plants?

My point is not about "relevance" – that the activity should relate to what the students care about – but about the purpose of graphing as an interpretive technique. The students are being taught an aspect of scientific thinking: Where does constructing such graphs fit into an authentic inquiry?

A comment in the facilitator-teacher notes on Day 28 says "Students didn't carry over a lot from the rockets study last year." This is ironic given that the students are not being encouraged to "carry over" anything about *the plants* either. And if the rocket exercise was handled in a similar way, how could they make sense of these graphs any better? Indeed, with all of the debates about the nature of abstractions (e.g., Clancey, 2001b), one might wonder whether abstractions would transfer better if they were contextualized in the first place.

One graph (see Fig. 2.4), developed by Rene and Janet (Group 5), says, "There are 47 different types of numbers used" and "How spread out are the height? 225" (which they show as the difference between the highest and lowest). Here we find two domains of analysis: properties of numbers and properties of heights. The discussion shows that the inquiry is not about plant heights and growth processes, but about the shapes of graphs. Without a reference for "spread out" there is no evaluative criteria for the difference: Why should it matter how spread out a graph is and whether one graph shows it or not?

Plants do get mentioned, but only with respect to "what's typical," not motivating the question about plant growth that might be answered by understanding variability:

Excerpt 10 [0:20:13–0:20:53]

```
0:20:13 teacher:    What about it helps you guys see that the
                    numbers are (.) spread and that they're uh
0:20:20 Ian:        Well:: =
0:20:20 teacher:    = >What a typical fast plant would be?< =
0:20:22 Kerri:      = Well to see how they're spread you have to
                    look up at the highest one (0.5) and then if
                    they're (0.7) so then like on the highest line
                    (0.8) that would be like (in) the highest
                    (1.0) like the (0.4) highest one and the
                    lowest (0.5) would be down here (0.4) and if
                    there's one along the same line then you just
                    look to see how far out this way it is
0:20:45 Kerri:      So if it (   )
0:20:47 Ian:        Or =
0:20:47 teacher:    = Ca can you guys circle on there where where
                    wherever you guys think a typical Fast Plant
                    is? by looking at the graph?
```

Here the numbers are unmistakably interpreted as representing the height of individual plants and growth rate ("fast plant"). But this is an exception. The classroom exercise focuses on conveying properties of graphs, such as "a bell distribution"; thus it is said that using data from later in the plants' life would produce "a distribution that looks more normal." In contrast, inquiring about the plants, what can we say about these plants on Day 19? How do various types of graphs help us understand the plants? Instead, the activity appears inverted, with the intention that graphing plant data will help us understand a bell curve! The focus is tool-centric as opposed to inquiry-centric. Rather than teaching about the nature of inquiry, the activity is teaching about the nature of graphs. What is the purpose of the exercise: Learning abstract math concepts ("spread out") or learning how to use graphing as a tool for doing science? Accomplishing both would make sense, but how could one omit the "math as tool" perspective?

Abstract Layout Talk vs. Sketching and Showing Each Other

A confounding issue is that the graph paper given to the students is for their final presentation; they can't write on it until they have created a design. Consequently, they perhaps waste time arguing in mid air, rather than sketching and showing design concepts to each other. Put another way, the presentation sheet is not a design tool, it must not be marked until the problem is solved. The problem this causes is painfully evident.

For example on Day 26 (Excerpt 2), they talk about where to start, 0 or 30? Couldn't they have simply started by sketching something and reflected on what it looks like? Kent says smiling, "Yeah but (.) do plants start out at thirty? Or at zero:?" [0:09:36], which is nice grounding in the experiment. But Garrett brings the group back to this set of numbers for D19, which starts at 30, "Well we're not really talking about plants" [0:09:39]. Caleb explains the graph is only about the numbers on the board: "Yes cuz (.) it doesn't make any sense to start at zero number when they're not even up there" [0:09:47]. Kent agrees and says, "But where should we star::t?" [0:09:55] with his stress of "start" and head gesture marking a shift in reference to the big empty space of the sheet. We see many gestures along imaginary axes (would could be trivially sketched) (Fig. 15.4).

Another group with three girls and Will are also gesturing to how to use the paper, what layout, what will fit, etc., all in words. Why don't they draw on another sheet and show a model of what have in mind? Why not use a ruler and show what will fit? Indeed, April says, "Just draw it firs:t" [Excerpt 3, 0:12:54]. Jewel sounds exasperated: "That's what I'm saying!" [0:12:21]. Drawing might avoid all the verbal banter. Yet she and the other students haven't even tried – they keep gesturing and talking, overwhelmed with the given constraints (Anneke: "How many numbers are (.) up there?" [0:11:39]) and possibilities (Anneke: "Could you put sixty three: things across here?" [0:11:41]). The single large blank page appears to have caused their method to get stuck on "planning by talking." The tools provided shape the methods used. The graph sheet is like one big fill-in-the-blank test form. (Interestingly, Edith uses her own notebook in attempting to communicate ideas.)

a

```
Kent:   = What's your nex::t?
        sixty-three((a))squares
        like this,
```

Fig. 15.4 Kent gestures to where they should start their graph. (Excerpt 2)

Example of Graphing as a Tool for Inquiry

To illustrate how the transactional aspect of graphing has been lost by viewing the graphs as having objective properties in isolation, I will present my own use of graphs for examining the classroom video.

In my experience, quantitative analysis is an essential part of ethnographic studies (Clancey, 2001a, 2002). In particular, video data can often be fruitfully categorized by activities, participant, location, and duration, leading to patterns that are not perceivable in the sequence of a transcript. For example, consider that some episodes appear to be relatively lengthy conversations between students without the teacher intervening. Also, I have implied that Tyler in some way dominates the graph presentation by his group. What are the frequencies and durations?

Consider the activity of Group 3 (Jasmine, Tyler, Edith, and Kendall) when they stood at the front of the room presenting the graph (see Fig. 2.3) produced by Group 2 (Anneke, Jewel, and April). Figure 15.5 represents their discourse, including the teacher's remarks (in black) and other students' questions or comments (dots and grey). I have chosen to view the episode as six periods[7] in which the students were presenting the graph, responding to the teacher or other students, or in which the teacher was directing (the third segment). In showing the episode in this way, one naturally questions the process by which it was created (you might want to look at the transcript corresponding to these segments to be sure you understand the categorization as representing the participants' understanding and whether you can see the alternation the graph claims).

Now we can view the group's presentation through the graph (Fig. 15.5). For example, we see that presenting the graph occurs twice, during about 3 min, which is about 25% of the total 13 min. This suggests a number of new questions: What affects the change between modes (presenting, responding, directing)? Who speaks with whom (is there a pattern of pairing)? Who speaks the most often? The longest during a turn? Who is relatively quiet? How do other groups compare? The graph presents the data so it can be perceptually grasped, revealing patterns (e.g., Tyler and "other" seem to appear together), leading us to ask numeric questions (e.g., how often is Tyler the one who replies to another student) and then pose new questions

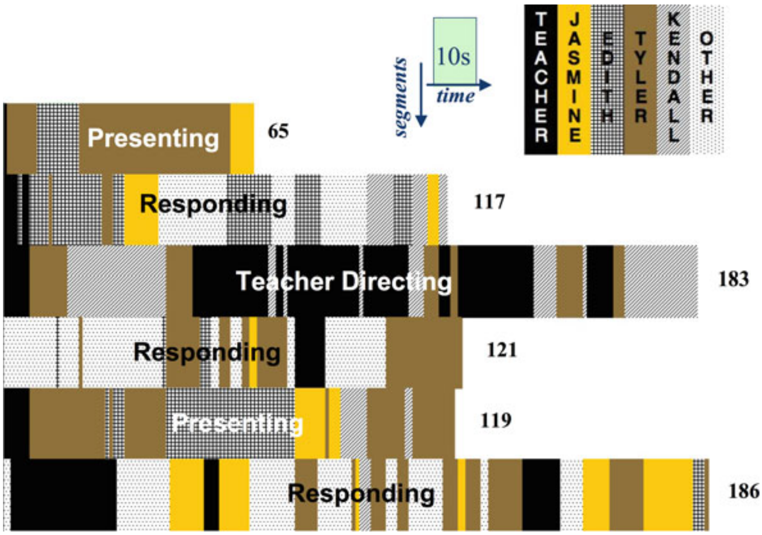


Fig. 15.5 One group's graph presentation (Excerpt 12)

about relations (are the other students directing questions at Tyler or is he jumping in to answer questions?).

Figure 15.5 shows how a graph can be a tool for discovery, as part of an inquiry about the classroom. The graph provides a way to structure the available data, formalizing impressions (e.g. sometimes the teacher appears quiet for long periods) so they can be measured and thus compared. In my experience, creating one graph often leads to wanting another to view the data in another way. Figure 15.6 was an attempt to test my hypothesis that Tyler was speaking most often during the presentation.

The graph surprised me by showing that Kendall spoke more than Jasmine. Before seeing the graph, I would have said that Kendall was relatively quiet. So my impression was wrong. Both researchers and participants can misjudge frequencies and durations of events (Clancey, 2001a, 2006; Clancey, Lee, Cockell, Braham, & Shafto, 2006).

These graphs illustrate the transactional perspective, as applied to teaching and learning, in two critical ways: in creating and sustaining the presentation's structure and in the nature of inquiry using a representational tool.

First, the segmentation suggests a pattern and episodic structure that no one in the classroom is strictly controlling, though they implicitly enable and contribute to its form. Individual behavior is constituted by the pattern (organized by it), just as individuals constitute the pattern (confirming a phase by acting in a way that continues it, e.g., continuing to present the graph while the group is in presenting mode). Thus, the structure of the class's activity and what individuals do is mutual, both influence each other, both in historical form (being influenced by what has come before) and in forward effect (by serving to orient what participants can do next). So I am claiming

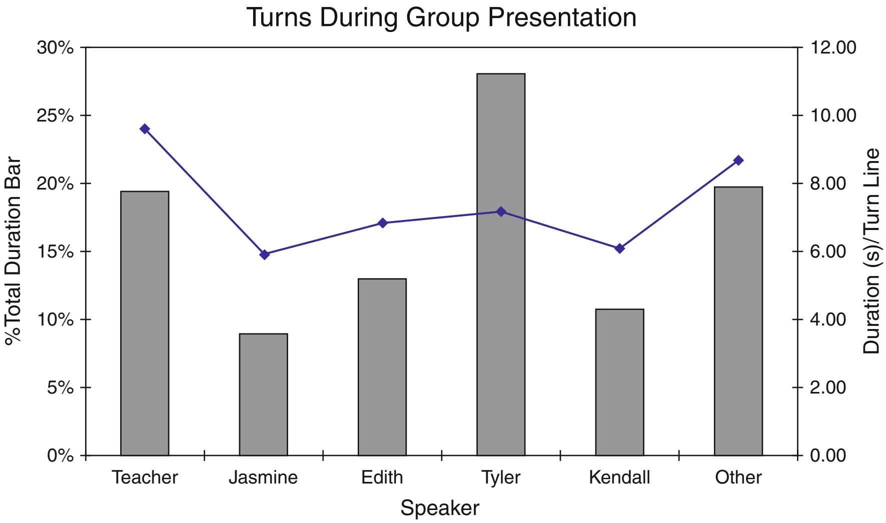


Fig. 15.6 Participant turns during the group presentation

that individuals conceive of the phases (What-We-are-Doing-Now) without naming them, necessarily viewing them consciously as being segments, or being aware of how they are alternating in a conceptually logical way (present-respond-direct-respond-present-respond).[8] However, it is reasonable to conjecture that the teacher is aware of redirecting the activity when he speaks, as I claim a more detailed content analysis would show in the development of the topics being discussed (i.e., I did not simply break the episode where the teacher speaks).

Second, the graph illustrates how representations (whether graphic or verbal) are instruments, as Dewey emphasized, a means for carrying out an investigation. The graphs I present are not my summaries or codifications of "what happened," but my means for transforming the details of the transcript to a visualization with salient perceptual relations, to numeric questions that compare and contrast the individuals and groups, to hypotheses about why events occur when they do, to general conjectures for prescriptive experiments to improve the students' experience – quite a leap to be sure.

The transactional aspect of the graph is realized by not viewing it as a means of presentation of something already understood, already objectified. These graphs are not created to portray the *result* of my inquiry, but are partly hypotheses, partly methods, partly summaries of how far I have gotten in my digging and shuffling and reorganizing of the available data. I use the graphs to convert the data into information through my perception, through computations, and through my poking around to find more patterns and connections. Thus my inquiry is a transactional relation among looking, transcribing, selecting and commenting on excerpts, graphing and inspecting of the graphs, and then going back to reconsider the validity of my segmenting and its application to other groups. My actions in creating and formatting the graphs may be chronologically described, but relate to perceptions and concepts that have no fixed form. My intention to demonstrate an idea (e.g., showing that Tyler is dominating) produced an artifact with evident patterns that changed the direction of my thinking. And when I present the graph in a new setting, I may interpret its significance differently. My past experience with the graph will partly determine my using it in the future – just as I have imported these figures from my workshop presentation. But when I reuse such artifacts, I may attribute and articulate other values and properties that were only tacit or even non-existent in my original conception, creating a new view of these classroom episodes.

So here lies my ultimate objection to what I see in the classroom video: The graphs are presented as a final product, just as the graph paper was protected from experimentation, so a clean "result" could be put forth. The class is not inquiring about plant biology or agriculture by relating the graphs and asking what other graphs are relevant to an "indeterminate situation" (Dewey, 1938, p. 104). They are myopically talking about the graphs as objects in their own right, removed from a plant-growing activity. Thus ironically, it appears that in this classroom the ideas of invention and presentation have been usefully applied, allowing the students to be creative and giving them the opportunity to address and respond to their classmates directly. But the idea of graphing, which is presumably the curriculum concept, could have been given a much richer scientific or engineering context, and thus conveyed a far more general – and transferable – understanding of how to use graphs to make sense of experience to uncover useful patterns and processes. For example, what is learned about the plants could be related to practical concerns such as lighting and fertilizing plants (e.g., designing greenhouses for Mars).

Correspondingly, I suggest that using graphs to analyze video quantitatively is essential for the scientific study of teaching and learning practices.

Conclusions

What does the transactional perspective, applied to a classroom video, suggest about "a program of studies for practice-based science of teaching and learning"? The research community has generally established that a great deal can be learned by studying classrooms (e.g., see *Journal of the Learning Sciences*). So really the question is focusing on the notion of *practice* and a *program* of studies.

From the perspective of a graph as a tool, the transactional perspective suggests designing learning activities as coherent *inquiry projects* that relate to practical goals. The term "inquiry" emphasizes authenticity – the students must be engaged in an activity that becomes problematic in their experience, as in trying to make something – and not just a chart itself!

A transactional perspective reveals the perceptual work of understanding a representation, and how this may involve rotating the image, distinguishing notations from designs (figure from ground), and imagining transformations (inferring and applying the design). Similarly, we are led to view interpersonal experiences as co-determined, avoiding trait-style explanations of behavior. We analyze a classroom episode as a performance by an *ensemble*, in which people are improvising, playing over and through each other. Actions are *commentaries* that promote re-conceptualizing (e.g., re-chunking and re-lating) what has transpired (i.e., what are the events of the past) and what the past means going forward. These performances are *accomplishments* with implicit structure, that constrain individual actions and that is sustained and developed by them.

This perspective makes salient functional aspects of behavior that were generally ignored by 1980s cognitive science studies of problem solving and instruction, in particular, the role of emotion in conceptual change. We develop a wholistic approach to understanding the experienced events, which facilitates relating biological and social aspects of learning: The conceptualized intangibles: Project, Activity (What I'm doing now), Attitude, Engagement/energy, Stage/Players/Experiences/Events, Persona – and "human factors": fatigue, hunger, postural discomfort, frustration.

The causal perspective of co-determination encourages us to recognize the uniqueness of situations, the inability to strictly control learning or activities, more broadly. We view an activity design (or the curriculum more generally) as a guide, not a fixed, optimal, or required path. We study each group diagnostically, emphatically, to understand its particular challenges, history, and opportunities.

It is difficult to imagine a claim that instructional design could be a science without specific hypotheses that certain aspects of an activity have predictable effects in certain situations. A transactional perspective doesn't rule out generalizations in the classroom any more than it ruled out generalizations in cell biology (section "Inter-action vs. Transaction"). One would expect at least rules of thumb for guiding discussions, and even activity toolkits that reliably produced energetic participation, questioning, and insights.

To conclude, I suggest that the following (at least) are required to develop a practice-based science of teaching and learning:

- Extensive observation and comparative analysis on different organizational scales (sessions, teachers, schools) – both repeating instructional activities like this graphing sequence and comparing with alternatives.
- Quantitative analyses of structure in classroom activities: Layouts, Phases, Rhythm, Participation, Regulation.
- Theoretical broadening of biological and social aspects, such as the musicality of ensemble performances in work groups, the nature and function of humor, the growth of identity, and the feedback relations of these dynamic processes: interpersonal regulation (articulation/co-construction) of norms, affective self-regulation, reflection and monitoring of progress, etc.
- Measurements that provide useful information for guiding learning.
- Extensive participation by stakeholders, including conversations within the home communities on what this research might practically accomplish.

In short, a transactional perspective might locate teaching in ever-broader contexts in which students will participate, helping them appreciate the theories, discourse, and tools of our society for structuring and interpreting experience.

Notes

1. This prescriptive notion of inquiry, often called "authentic learning" in the situated cognition debates (Brown, Collins & Duguid 1989), relates to an instructional design promoted as "cognitive apprenticeship" (Collins, Brown & Newman, 1986).
2. I am grateful to Jim Garrison for pointing out this passage. Garrison (2001) provides a highly useful introduction that complements and further explains the ideas I present in these sections.
3. On revising an early draft, I removed all colloquial uses of the word "interaction." In most cases, I now say "episode," which has the advantage of indirectly implying that I have bracketed the video stream and am viewing the resulting sequence as being a unit with certain properties. In other places I say "participation," e.g., in referring to the teacher's participation style (manner of being involved) during the students' presentation of graphs to the class. Later, on reading Burke (1994), I realized that I had been identifying "inquiry" with "solving problems," and went back to emphasize its more fundamental character.
4. Glenn's (2003) conversational analysis of laughter as a social interaction also distinguishes between reflex and intentional laughter, which he characterizes as two types of analysis, physiological and social. I am distinguishing instead between two kinds of experience with different temporal and attentional characteristics. Perhaps more importantly, I am viewing the episodes more broadly in terms of *play*, and not concerned with laughing *per se*.
5. This analysis is supported by theories that humor involves sustaining "mutually contradictory frames of interpretation" (Mulkay, 1988, pp. 32–35, cited in Glenn, 2003, p. 21). In contrast with the view that laughter involves a kind of physical relief of tension when attempting to relate incommensurate frames, a *humorous attitude* is an emotional means of keeping oneself oriented, while otherwise inconsistent conceptualizations are simultaneously active. This follows from Bartlett's (1932) analysis of the role of attitude in the action of remembering. Also, viewing the episode as a *communication*, Bateson's (1972) analysis of play suggests that "The message 'This is play' establishes a paradoxical frame" (p. 184), in which "These actions, in which we now engage, do not denote what would be denoted by those actions which those actions denote" (p. 180). Thus, Tyler's actions such as waving the paper in LS's face are not an attempt to disrupt the group and end the task, but perhaps to instill a different manner of working or relating.
6. An exception is Binsted and Ritchie (1997), which models humor as text manipulation using semantic networks, with some limited success in creating puns.
7. The six periods correspond to Excerpt 12 starting at [0:42:23], [0:43:33], [0:45:29], [0:48:31], [0:50:33], and [0:52:31]. Figure 13-5 was generated from an earlier transcript using a video without embedded time code, in which the start times were determined to be [0:42:28], [0:43:33], [0:45:30], [0:48:33], [0:50:34], and [0:52:31], ending at [0:55:39]. My original transcription also did not include interjections (e.g., [0:50:34–0:50:52]); I define a *turn* to be when one speaker has the floor and others are just exclaiming or briefly asking for clarification. With this qualification, the differences between Figure 13-5 and Excerpt 12 in Appendix B do not significantly affect the comparison of total and average turn durations for each speaker (Figure 13-6).
8. These categories are similar to those used in Conversation Analysis (e.g., Sacks, 1984), though my attention to details in the transcripts is much less formal.

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Chapter 16
On Plants and Textual Representations of Plants: Learning to Reason in Institutional Categories

Roger Säljö

Introduction

The transactional inquiry perspective for understanding learning that William Clancey articulates and puts to use in his chapter is informative and suggestive. It is obvious that this extension of Dewey's ideas has a lot to offer for those of us who are interested in the problem of how to theorize learning practices. The presentation shows how remarkably up-to-date, relevant, and rich Dewey's ideas about learning as inquiry continue to appear for new generations of readers. This is truly one of most significant sources of inspiration in the literature for anyone interested in learning and in understanding how learning practices in schooling can be developed so as to be relevant for the needs of young people and for society.

Some elements of Clancey's argumentation I find particularly appealing. The interdisciplinary ambition of attempting to bridge between biological, cognitive, and social processes, I read as an explicit attempt to respect the complexity of the phenomena we are studying. Learning is an object of inquiry for scholars in an increasing number of disciplines, all the way from microbiology and neurochemistry via psychology and cognitive science over to economics, history, sociology, and several other of the human sciences. Therefore we have to be conscious of what the various perspectives have to offer, but we also need to be aware that the different levels of analysis stand in complex relationships to each other. Moving from one level of analysis to the next requires analytical awareness and is in itself often a challenging research undertaking.

The elaboration provided by Clancey of how a transactional perspective à la Dewey and Bentley (1949) is something radically different from an inter-actional perspective is equally enlightening. Inter-action is exchange between what is already there; transaction is characterized by transformation of people, knowing, and practices. As Clancey puts it, the "essence of transactional is to view stimuli,

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intent, visualizations, etc. as both reorganizations of experience" and, simultaneously, as "orientations for the current activity" (p. 254). In this non-linear and cyclic interpretation of human thinking, the "situation and understanding co-develop; the causal relation is dynamic" (p. 249), and simultaneity of events is as significant as sequentiality. Such dynamic transformations in which people and activities change and reorganize their perceptions and ways of reasoning continue to be challenging objects of inquiry for research traditions that in many ways still suffer from the rather paralyzing effects of dualist and positivist notions of how to analyse human beings and human action.

Both these premises, the multidisciplinarity, and to some extent elusiveness, of the object of study, and the idea of transformation and non-deterministic causation, have something in common; they seek to preserve the integrity and complexity of our object of inquiry when studying human learning. As Dewey repeatedly reminds us in his texts, isolating levels of scientific inquiry from each other, or separating the organism from the environment, is a mistake. Such an analytical strategy removes the dynamics of the very phenomena we set out to explore. The atoms thus subjected to scrutiny cannot be integrated at some later stage in the research process. The current specialization and fragmentation of research in many fields testify to this development. We have an increasing number of isolated islands of inquiry that do not speak to each other in very productive manners. Yet, besides the analytical problems of connecting levels of inquiry in a convincing manner, there is of course the strategic question of the relevance of different levels of inquiry for various purposes. For many reasons, we cannot always attend to all levels that would be relevant. We have to make priorities depending on, for instance, the purposes of our work and the audiences we have in mind. Just as students should work in "purposeful contexts" (p. 269), to use Clancey's terminology, scholars find themselves engaged in research activities with different "purposes."

I also appreciate the rhetorical strategy Clancey adopts in which the transformative elements are obvious. As he analyses how the participants struggle with the problems of how to interpret graphs and illustrations, he intentionally puts the readers in the same situation of transforming their perceptions of what goes on in the classroom. Patterns and regularities in communicative activities become visible, sometimes in surprising manners, when they are mediated through such representations. The use of such tools enriches our understanding of the nature and progress of the activities that the students engage in. This illustrates how our seeing is mediated by cultural tools, and the central role that such resources play in *re*-searching the dynamics of human interaction.

My comments have the character of reflections and some suggestions for additions to the perspective and analyses presented. I will comment on three points. Initially I want to make some remarks on the metaphor of learning itself. Second, I want to point to what I consider critical about what we see in the classroom interaction: the institutional embeddedness and logic of the communicative practices. Third, I want to make some comments with respect to issues of interdisciplinarity and research on human learning. In particular, I want to comment on Clancey's claims that neuropsychological discourse offers a meeting ground for our ambitions to transcend simplistic, mono-disciplinary notions of human learning.

Learning: A Conceptual Comment

In a classroom we expect learning to take place. However, the term learning is a slippery one, and it is used with different meanings and for many purposes. It is also problematic in the sense that it is generally used with positive connotations only. There are very few scholars who study how people learn prejudices, to commit fraud, or how they develop connoisseurship in activities that may be detrimental to themselves and others. The socializing functions of being bored are also generally not given very much attention in educational research. Can we really claim that students who do not participate actively in the exercises we see on the video, and who perhaps remain passive during lessons, are not learning? Is it not reasonable to assume that they are learning a lot about themselves and maybe their difficulties to understand and contribute? There is an interesting bias in Western culture it seems, where the concept of learning plays a very important role for how we measure and understand success and failure in society. The concept of learning is part of an optimistic story about ourselves and our children, and we prefer such processes to be successful. The recent reactions to international comparisons of educational achievement, such as PISA and TIMSS, testify to how important issues of school achievement have become. Ministers have to stand in their parliaments and blushingly admit that the students of their respective countries are not "learning" well enough.

This fact that learning is polysemous, and that the term is used both as an analytical object of inquiry in research and as the core element of a normative discourse of pedagogy is the cause of much confusion when it comes to developing a fruitful relationship between research and practice. Many theorists oscillate between these two interpretations, sometimes studying allegedly neutral "mechanisms" of learning, sometimes making prescriptive claims about how to organize learning.

Elements of tensions of this kind are present in Clancey's text. On the one hand, he argues along the lines of a rather traditional process-product conception of learning and education within a largely functionalist interpretation of schooling. Thus, it is "difficult to imagine a claim that instructional design could be a science without specific hypotheses that certain aspects of an activity have predictable effects in certain situations" (p. 276). The role of research in this conception of learning/education seems to be the conventional one of providing evidence for what works, and the loyalty is to the curricular conceptions of learning and progress. But there is also another voice present in the text. As researchers of practices of schooling, we should, Clancey argues, "recognize the uniqueness of situations, the inability to strictly control learning or activities, more broadly" (p. 276). Research with this ambition should help us study "each group diagnostically, emphatically, to understand its particular challenges, history, and opportunities" (p. 276). This to me appears as a call for research attending to student perspectives, studies that focus the unpredictable transformations of people and activities. Learning, especially in our society, is much more than mastering curricular contents in accordance with some pre-specified criteria. Learning is about relevance and personal meaning making, about developing as an individual. Learning in a democratic society requires the active participation and commitment of individuals, and education must be organized so as to engage people with different backgrounds. Education is an ideological enterprise. Within this conception of research, and within a more critical knowledge interest, we might even study how practices of schooling sometimes block learning for many children, for instance, those whose backgrounds have not prepared them for the literate activities that dominate mainstream schooling. In this more ideological conception of education and learning, developing practices that are based on "deliberation" and active attempts to encourage and secure student interest and participation seem more promising for informing pedagogy than traditional standardized outcome measurements.

To avoid privileging traditionalist interpretations of learning (which, by the way, always tend to emphasize the more reproductive elements of schooling), it is important to consider what goes on in school as a particular form of activity; what we see are activities that are organized on the basis of institutional interpretations of what learning is all about. So, let us research teaching and learning practices first and foremost as instances of communication, and let us try to understand what counts as learning in these particular institutional and historical circumstances. We should not take the meaning of the concept as a given. In my opinion, learning is best studied if we regard it as an omnipresent element of human practices (Lave, 1993). One can always raise the question of what is learned in a particular activity. This is an issue well worth exploring. Resistance and non-commitment to participation in educational practices are also outcomes of socialization and learning. They are by no means accidental by-products.

Learning in Institutional Settings

As I watch what takes place in this classroom, I am struck by the institutional character of the activities; what we see is the activity of studying rather than learning. What goes on here is a relatively modern version of an activity system that we can find in many parts of the world and that has been around for a long time. In Western culture we can date it back to the introduction of the first writing system developed by the Sumerians well over 5,000 years ago (Burns, 1989; Kramer, 1981), and maybe it has an even longer history elsewhere. Factors such as the choreography of the interaction, the design of the room, and the artefacts present, tell us what social practice this is. It would only take a few seconds of watching the video before almost everyone would identify the activity as an instance of schooling. The situation unfolds within a familiar framing (Goffman, 1986) that everyone seems to share; the participants know what to do and how to contribute (even though they momentarily are more or less active, cooperative or challenging, but that is another story). Even the jokes are triggered by institutional framings, such as when the teacher is heard as mispronouncing "bin" [Excerpt 8, 0:29:03–0:29:07].

So, these are institutional practices that have a long history, and that have been amazingly successful if we consider how they have spread across the world. We are used to talking about the failures of instruction and education, but the staying power and spread of these practices are truly amazing. The spread of literacy, for instance, from small elites to the majority of the population is a consequence of this mode of organizing cultural reproduction. It is in circumstances such as these that a young person acting as a student becomes "an inheritor of the funded capital of civilization" (Dewey, 1897, p. 77) in our societies. The classroom context is where they encounter a range of activities and discourses that to some extent overlap with what they are used to, while in other respects these practices will be less familiar and often strange and abstract. Learning to "do" school, and how to assume the identity of a student, are important elements of the socialization that the institution offers. It is in settings of this kind that children encounter institutional traditions of sense-making, and they will be evaluated on the basis of how good they are at decoding these. Knowing here, by and large, means to be able to think and reason in institutional categories that are different from those of everyday life.

In the interesting third section of his analysis, the one about purposeful context, Clancey remarks that the activity seems boring for the participants, and that it is questionable if the students are doing and reporting on a plant experiment in any genuine sense. The discussion quickly becomes tool-centric rather than inquiry-centric, even to the extent that students later on "are just manipulating numbers" (p. 269). And they seem to do this with little reference to what these numbers refer to as illustrations of an experiment with plants. It seems obvious to me that to understand how the interaction unfolds, one must be aware of the fact that the students are engaged in the particular communicative practice that we refer to as an exercise. This is a specific institutional activity where what you do is consequential for the participants as students but maybe not to the same extent as persons. The shifts in the contributions by the students, and the variation in their interests and their willingness to contribute to the public discourse, to a large extent reflect this particular situatedness of their activity.

Given this framing, the tool-centeredness of the communication is by no means accidental. It reflects a typical institutional pattern in which living plants are converted into illustrations for the purpose of doing exercises that, in principle, could be about anything. This is a particular form of learning and cognitive socialization: relating to experiences in a world of physical objects, while at the same time converting these experiences and objects into illustrations for the particular literate practices that are the goals of learning of the institution.

The tool-centric nature of institutional practices and meaning making has been beautifully illustrated in studies of how children reason when introduced to so-called word problems in elementary mathematics teaching (for a summary, see Verschaffel, Greer, & De Corte, 2000). In such situations, children *qua* students are required to move between everyday accounts of familiar activities, on the one hand, and, on the other, the discursive practices that rely on mathematical notation and operations.

For instance, Verschaffel, De Corte, and Lasure (1994) showed how children, when confronted with the following problem: "John's best time to run 100 m is 17 s. How long will it take him to run 1 km?," tend to think in tool-centric, institutional terms. Well over 90 per cent of the students participating gave as their answer the multiplication $10 \times 17 = 170$ s. A few per cent gave any indication that the task cannot be solved in any meaningful manner. Even Japanese children, normally outperforming children from many other parts of the world in early mathematics learning, reacted in this manner (Yoshida, Verschaffel, & De Corte, 1997). There was no sign that the Japanese children were more prone to consider if the information provided was relevant and sufficient for solving this problem. Tool-centric thinking and "manipulating numbers" are not unfortunate consequences of poor pedagogy; they are essential features of communication and learning in institutional settings. This is largely how schools do business.

Vygotsky (1986) paid considerable interest to a version of this particular issue of how "spontaneous" concepts are learned, and how this learning process differs from how "scientific" concepts are acquired. Although Vygotsky, in my opinion, exaggerates this difference, I think the classroom exercise illustrates interesting features of the differences between spontaneous concepts (where plants are talked about in terms of their function, smell, beauty and other characteristics), and scientific concepts where the world is modelled and interpreted within rather different, and more abstract, discursive practices. Thus, the students here encounter a situation where they are in some sense required to alienate themselves from a sensual interaction with plants and instead use them as material for a specific representational practice that they do not feel completely familiar with (and, as Clancey hints at, we are not certain to what extent the teacher feels entirely at home when discussing specific features of the representational tool such as the "spread" of the observations made). But, again, putting them in this situation is an essential element of what schooling is all about (Cole, 1996).

To understand how the practices – as educational practices – unfold, we therefore have to focus the difficulties students have in understanding the nature of the expected meaning making. It is obvious from the conversation that this exercise is abstract for them, but, nevertheless, this is a prototypical example of the developmental paths that modern schooling offers young people. So, the alienation they sometimes seem to experience while working, and the occasional confusion about what to do, are to a large extent functional. They are essential ingredients in what we must understand as the social organization of learning.

These dilemmas of "how institutions think" (Douglas, 1986), on the one hand, and meaning making by students, on the other, were central to Dewey. Thus, "there can be no doubt that a peculiar artificiality attaches to what is learned in schools" (Dewey, 1966, p. 161), he argues. In institutional settings, students are continuously put in situations where what they experience "does not possess for them the kind of reality which the subject matter of their vital experiences possess", and they "learn not to expect that sort of reality of it" (loc. cit.). The hermeneutic practices that are introduced, and insisted upon, give preference not just to "higher order" conceptual categorization, but to categorization that is grounded in institutional traditions of perceiving and reasoning. Again, it comes as no surprise that Dewey had these problems clear in his mind. Learning science and scientific inquiry, he argued, is about acquiring knowing that "does not stand for the things directly in their practical use in experience, but for the things placed in a cognitive system" (Dewey, 1966, p. 222). All these rich scientific terms and concepts "have primarily an intellectual value and only indirectly an empirical value", and we "cannot procure understanding of their meaning by pointing to things, but only by pointing to their work when they are employed as part of the technique of knowledge." (loc. cit.). Techniques of institutional knowing are what the students face and have to grapple with in this classroom.

Neuropsychological Inquiry, Categorization, and the Shaping of Cultural Minds

Clancey sets out by arguing that he wants to test a hypothesis: "understanding what happens in human behaviour, and specifically where and how learning is occurring, is facilitated by considering the biological aspects of cognition" (p. 247). Even though it is easy to subscribe to the Deweyan position of not separating the mind, the psyche, the person, and the neural center, as essential for understanding learning, there is still an important problem that Clancey formulates himself: "the question is how is the biological nature of learning manifested in a classroom?" (p. 254). And the extension of this question is of course the issue of how biological and neuropsychological knowledge can be used as a resource for understanding and facilitating learning in interactive and institutional settings.

First of all I want to point out that I do not find the analysis that Clancey presents, for instance in the section on humour as a reflex vs. as intentionally produced, as very much grounded in neuropsychological concepts or assumptions. For instance, the in-depth analysis of playful behaviour as mutually constructed I find valuable without interpreting it as exclusively, or even mainly, neuropsychological. The claim is that when the activity the students and the teacher are engaged in is viewed as transactional, this "reflects the neuropsychological nature of conceptualization – a coordination process that is simultaneously compositional (with blending of conceptual), sequential, parallel (in creating and relating perceptual features and categories of different modalities), and emotional" (p. 264). In my opinion, this analysis illustrates in a convincing manner illustrates the transactional nature of human interaction and it testifies to our impressive "conceptual ability to blend multiple activities" (loc. cit.), some of which we are only made aware of tacitly. However, this analysis is interesting to me since it gives a rather detailed account of how the interaction is organized, and why it can be regarded as transactional. The claim that the accomplishments of the participants are grounded in neuropsychological processes does not add very much to the understanding. Non-linearity, multidimensionality and playfulness can equally well be understood as primarily interactional achievements by the participants.

It seems obvious that categorization is fundamental to human knowing. Categories allow us to perspectivize the world and to contextualize it in specific manners suited to the needs of the activity we are in (Mäkitalo & Säljö, 2002). The activity in the classroom, and the perceptual work students are doing, to a large extent are about learning to see and notice within specific institutional and cultural practices (Goodwin, 1997). This cultural/institutional mode of seeing, of course, has a neuropsychological basis, but the relationship between what happens at the level of neuropsychology and the cultural categories employed as conceptual tools in this practice is distant, and we have to treat this relationship with considerable care. Our biological mechanisms of perception have been with us for a long time, and they are highly flexible and adaptable. They are resources for perception and reasoning, but they do not determine how we construe the world, and the constraints they imply in meaning making practices of the kind studied by Clancey still leave many alternative interpretations open.

What is at stake here is the appropriation of specific institutional practices, categories, and ways of "seeing". What the children are supposed to learn about how to organize information in terms of columns and rows is a cultural practice that is not universal and that has specific roots. It goes back to the early beginnings of the very first documentary practices in ancient Sumeria, where tax registers and other similar literate techniques for creating and maintaining social order were introduced (Goody, 1987, p. 274; Ong, 1982, p. 99). This is a very specific cultural mode of representing the world, which is interesting since it is so extremely reductionistic as Goody (1977, p. 52ff) has demonstrated in detail. The functionality of the tool lies in the manner in which it configures information relevant for specific institutional traditions for making meaning, and it is a wonderful instrument for disregarding everything else. The point of the exercise is introducing the students to this form of perception and perceptual work, and to instruct them in how to make relevant noticings. Or, in other words, the students are learning how to engage in meaning-making that is accountable to very specific institutional traditions of organizing and presenting information.

So, although I agree about the necessity of taking into account the multidisciplinarity of our object of analysis — human learning — I remain less optimistic about what biology and neuropsychology has to offer when it comes to broadening our knowledge about this type of institutional learning, or when we want to reorganize school practices. As a research exercise I find such multidisciplinarity fascinating, but as an instrument informing us how educational practices should be developed, the promises of modern biology do not seem so great to me. What is apparent to me is the enormous flexibility that our biological apparatus has in allowing for variations in forms of knowing and understanding. In what Donald (1991, 2001) refers to as a "theoretic culture," relying largely on literacy and a broad range of external memory systems for storing and codifying our collective memory, the link between neuropsychological resources and human learning becomes rather indirect and abstract. Or, in Clancey's terminology, the "coupling" between levels of categorization and organization at the level of biology and at the level of culturally relevant knowing, respectively, becomes weak. I would even argue that the relationship is often indeterminate; what happens at one level cannot be reduced to other. Even the constraints that we can perceive at one level may have no counterpart on the other.

As Donald points out, in these circumstances, learning is to a large extent a matter of mastering cultural techniques (or tools, in Vygotskian language) of knowing, and the graph and the number system are good illustrations of this. These tools are expressions of cultural institutions that could have been different. Thus, what we are observing in the classroom is a coordination process in which certain cultural practices and categories are privileged (Wertsch, 1998) at the expense of others, and in which people are attuned to interpreting the world in specific manners. This is a very important element of modern schooling (but in a more general perspective, it is only one of its many functions). My guess is that our biological apparatus can tolerate an enormous variation in cultural categorizations and cultural knowing. This implies that the space for intervention by the educational system, and by cultural experience in general, when it comes to shaping cognition is considerable. Literate skills, for instance, are largely the products of educational intervention. At the time of the invention of the printing press, and before the spread of books and schooling, the proportion of European populations that could read was low (literacy rates of between 5 and 20% are often given in the literature, cf., for example, Cressey, 1980; Engelsing, 1973; Maas, 2001). In a relatively short time, the situation changed dramatically in some regions of Europe and almost universal literacy (at some level) was achieved. In our present society, the expected levels of literacy and other information skills have increased rather dramatically, and it is not clear to me that there are any specific biological limitations to how far this development can go.

Let me just mention another argument for why I remain rather sceptical about the "coupling" between neuropsychological and cultural forms of categorization. This is a more personal hang-up, and it is not directly to the sophisticated analysis and argumentation that Clancey presents. It is often quite easy to point to constraints at the level of biology to justify success and failure in terms of mastering cultural skills. Not so long ago, children with various forms of communicative handicaps were often considered un-educable and/or were sent to special institutions with very low expectations about their developmental potentials. Categories such as feeble-minded, imbeciles, idiots, half-idiots, morons and many more (cf., for instance, Trent, 1994) were introduced to construe "kinds of people" as Hacking (1986, 2002) puts it. These categories were generally grounded in alleged biological "facts" about the capacities of people to profit from educational experiences. Psychiatrists and psychologists construed tests that were claimed to measure these deficiencies and the results were used as proof of the un-educability of these children. In hindsight, we realize that this argumentation was a set of self-fulfilling prophecies, since the categories were part of a machinery that effectively marginalized the children from education and other forms of learning experiences. Many of these groups now receive education suited to their abilities and many of the can develop advanced literate skills. Indeed, one could probably make the argument that these children were the ones that more than any other groups profited from instruction and educational intervention into their lives. When the attitudes changed and pedagogy developed, their learning potential was found to be way above what the previous classifications suggested. Today we see the proliferation of new categories that in similar manners allude to alleged biological obstacles to learning (Hjörne & Säljö, 2004, 2007). These categories, producing new "kinds of people" with learning difficulties, largely come from the field of neuropsychology, and again there is an obvious risk that the outcome will be segregation. A diagnostic culture, when introduced into education, often has this result. But, of course, this does not mean that neuropsychological knowledge is not important for understanding learning at a general level and in many situations. My worry here concerns how such knowledge is used in the particular context of institutionalized education where research findings and ideologies mix in complicated ways.

To conclude, Clancey's illustration of the potentials of the transactional perspective to me is another proof of how much there still is to learn from Dewey as an analyst of learning and as philosopher pointing to the potentials of education to transform human beings. In particular, I think the manner in which Clancey uses the transactional perspective for rather detailed analyses of interaction in educational settings is innovative and inspiring. It is the combination of detailed observation, in-depth analysis, and sound theoretical underpinnings that we can advance our understanding of how to theorize learning practices inside and outside educational settings. Using Deweyan language, this is a good point from which we can carry on potentially rewarding deliberations in the field of learning research.

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Chapter 17
The Contributions of the Transactional Perspective to Instructional Design and the Analysis of Learning in Social Context

Paul Cobb

In his chapter, Clancey develops his transactional perspective by taking an interactional viewpoint familiar to cognitive psychologists as his primary point of reference. Clancey first clarifies that researchers who adopt the interactional view conceptualize social settings in terms of the interacting properties of *pre-established* constituent entities. He then goes on to emphasize that the transactional perspective that he favors holds that none of the constituents of a social setting such as a classroom can be adequately described apart from the very setting that they collectively comprise. Clancey goes on to clarify an important methodological entailment of the transactional perspective, namely that the researcher should be consciously aware that analysis and reflection inevitably involve selective emphasis and choice. In light of this entailment, I should clarify that my comments on Clancey's chapter reflect my concerns as a mathematics educator who is interested in issues of instructional design and students' mathematical learning as it is situated within the social setting of the classroom.

In this commentary, I argue that the distinction that Clancey draws between the interactional and transactional perspectives is a difference that makes a difference when theorizing learning and practice (cf., Bateson, 1973). I first follow Clancey in drawing on Dewey's pragmatism to clarify the primary criterion that I use to assess the potential contributions of his transactional perspective. Against this background, I then focus on specific aspects of Clancey's analysis to illustrate its relevance in orienting instructional design and the analysis of learning in classroom settings.

Usefulness and Truth

My discussion of Clancey's chapter is grounded in the assumption that mathematics education can be productively viewed as a design science, the collective mission of

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which involves developing, testing, and revising designs for supporting envisioned learning processes. This characterization of mathematics education is inclusive in that the designs might be formulated at the level of a national educational system, a school or school district, or a classroom. In addition, the learning processes of interest might be those of individual students or teachers, of classroom communities or professional teaching communities, or of schools or school districts viewed as organizations. Furthermore, the characterization of mathematics education as a design science orients us to construe learning broadly by treating individual and collective identity as integral aspects of activity and practice.

A key criterion that I employ when assessing the contribution of any theoretical perspective including concerns its potential *usefulness* in orienting and guiding the development, testing, and revision of designs for supporting envisioned learning processes. This criterion is consistent with Clancey's transactional perspective in that both characterize theoretical perspectives as conceptual tools. However, it is essential to sharpen the criterion of usefulness before proceeding by clarifying what it might mean for a theoretical perspective to contribute to the collective enterprise of mathematics education. In addressing this issue, I draw on Prawat's (1995) discussion of the three types of pragmatic justification identified by Pepper (1942).

The first type of pragmatic justification is purely instrumental in that actions are judged to be true if they enable the achievement of goals. Prawat (1995) indicated the limitations of this formulation when he observed that "a rat navigating a maze has as much claim on truth, according to this approach, as the most clear-headed scientist" (p. 19). The second type of pragmatic justification focuses not on the achievement of a goal, but rather on the *hypothesis* that led to a successful act. This type of justification is also inadequate for our purposes because it treats hypotheses solely as tools for the control of nature. Toulmin (1963) demonstrated the limitation of this latter view when he clarified that instrumental control is a by-product of science's primary quest for insight and understanding into the phenomena under investigation.

The third type of pragmatic justification, which Pepper (1942) calls the qualitative confirmation test of truth, foregrounds the development of insight and understanding. This type of justification builds on Dewey's (1890/1969) analysis of the function of thought and of the process of verification. Briefly, Dewey viewed ideas as potentially revisable plans for action and argued that their truth is judged in terms of whether they lead to a satisfactory resolution to problematic situations (Westbrook, 1991). In taking this stance, Dewey equated experience with physical and conceptual action in a socially and culturally organized reality, and maintained that it is characterized by a future-oriented projection that involves an attempt to change the given situation (Sleeper, 1986; Smith, 1978). He, therefore, contended that foresight and understanding are integral to thought, the primary function of which is to project future possibilities and to prepare us to come to grips with novel, unanticipated occurrences.

This characterization of thought is integral to Dewey's analysis of verification as a process in which the phenomena under investigation talk back, giving rise to surprises and inconsistencies. He clarified that some of these surprises can be accounted for relatively easily by elaborating underlying ideas, whereas others constitute conceptual impasses that typically precipitate either the reworking of ideas or their eventual rejection (Prawat, 1995). The crucial point to note is that Dewey viewed verification as a process in which theoretical ideas are elaborated and modified. As Pepper (1942) put it, ideas judged to be true are those that give insight into the phenomena that serve to verify them.

In the case of mathematics education, ideas are potentially useful to the extent that they give insight into learning processes and the specific means of supporting them. However, as Dewey realized and as Clancey illustrates, these ideas are not simply confirmed unchanged or rejected during the process of testing and revising designs. Instead, the ideas evolve in the very process of being confirmed and verified. In this formulation, *the truth of fallible, potentially revisable ideas is justified primarily in terms of the insight and understanding they give into learning processes and the means of supporting their realization*. This is the criterion that I use when considering the potentially useful work that the transactional perspective might do in contributing to the enterprise of formulating, testing, and revising conjectured designs for supporting envisioned learning processes. To this end, I first discuss the Clancey's analysis of tools, instructional activities, social interactions, and norms as constituents of the classroom setting, and then focus on his treatment of subject matter content and of modeling.

The Classroom Setting as an Emergent System

On my reading, Clancey's transactional perspective characterizes the classroom as an emergent system in which the constituent elements are reflexively related. Reflexivity is an extremely strong relationship and does not merely mean that the various constituents are interdependent. Instead, it implies that they do not exist except in relation to each other (Mehan & Wood, 1975). As an example, in analyzing the first of the three video-recorded lessons, Clancey notes that the graph paper the students were given was constituted as a fill-in-the-blank form rather than a design tool. This observation illustrates his more general claim that tools, as elements of the classroom setting, are constituted in the very process of being used. The properties that the graph paper came to have for the students, and thus its affordances and constraints, were both situated within and contributed to the constitution of the classroom as an emergent system. The transactional perspective therefore indicates the importance of analyzing how the teacher and students jointly constitute particular ways of using tools in the course of their ongoing interactions. This is significant from the point of view of design as tools are a primary means by which designers attempt to support students' learning.

Similar comments can be made about instructional tasks. In the case that Clancey analyzes, the students were instructed to use the graph paper to organize the Wisconsin Fast Plants® data so that it would be possible to determine typicality and spread. Clancey demonstrates, convincingly in my view, that inquiry shifted from the "plant domain" to the "graph domain" during the concluding whole class discussion. The contrasting case of statistical data analysis that he develops by describing his own activity of constructing graphs illustrates that shifts of this type are consequential in terms of students' mathematical learning – it is a difference that makes a difference from the point of view of design. As G. Cobb and Moore (1997, 1995) clarify, statisticians seek to develop insights by discerning patterns not in numbers, but in measures of attributes of the phenomenon under investigation. To be sure, statisticians debate the usefulness of methods and ideas, but they do so within the context of actual or envisioned investigations, thereby constituting the methods and ideas as conceptual tools of inquiry. In my experience of conducting classroom design experiments, subtle yet consequential shifts of the type that Clancey documents are frequent occurrences. Clancey's transactional perspective foregrounds the importance of distinguishing between *instructional tasks* as they are envisioned by the designer or the teacher, and *instructional activities* that are constituted as instructional tasks are enacted in the classroom.

In addition to orienting us to analyze how tools and instructional activities are actually constituted in the classroom, the transactional perspective directs us to view the teacher and students as mutually adjusting their actions based on their ongoing perceptions of what the other is doing, noticing, and so forth. On my reading, this stance to social interaction is compatible with the basic tenets of symbolic interactionism as outlined by Blumer (1969). This is not surprising given that Blumer drew heavily on the work of Mead (1934), a colleague of Dewey at the University of Chicago. As Clancey suggests, the notion of people reciprocally adapting their actions to each other implies that rather than simply enacting pre-determined roles, they instead collectively improvise their parts. A number of symbolic interactionist analyses in mathematics education serve to complement this emphasis on creativity and agency by also attending to structure in the form of patterns of interaction. Two seminal papers in this regard are those of Bauersfeld (1980) and Voigt (1985). As an illustration, Voigt identified the *elicitation pattern* by analyzing interactions in a number of German mathematics classrooms. The teacher and students in the case that Clancey analyzes appeared to interactively constitute this same pattern during the concluding whole class discussion.

The four successive phases that Voigt distinguished in this pattern can be summarized as follows:

- The teacher asks an open-ended question or poses an open-ended task and elicits responses from the students.
- Students present their responses and the teacher does not evaluate their contributions but instead calls on other students who indicate that they have developed different interpretations or solutions.
- The teacher begins to give increasingly explicit cues about the desired interpretation or solution until a student produces the desired solution.
- The teacher gives a reflective summary of the exchange that explicitly relates the desired response to the original question or task.

In the case at hand, the teacher made an initial elicitation when he asked the students, “Well what about graph helps you see what the typical Fast Plant would be?” [Excerpt 9: 0:04:24]. The students dominated the conversation during the following 5 min and made a number of proposals that the teacher did not evaluate. However, the teacher eventually attempted to give a cue when he introduced the hypothetical data point of 555 and asked whether of the graphs enabled the students to see the spread in the data more easily.

Excerpt 9 [0:10:28–0:11:38]

0:10:28	teacher:	Um: I’m wondering which graph would show: better (1.3) the spread?
0:10:33	teacher:	So let’s let’s ignor:e two hundred and fifty-five for a minute and say instead of that plant being >two hundred and fifty-five< (0.5) it was ⌈five hundred fifty five.
0:10:39	teacher:	⌊((*writing “555” on board*))
0:10:42	teacher:	Oka:y. Does that does that feel like it’s quite a bit different (0.4) than two fifty-five ’kay?
0:10:47	teacher:	So would you say would everybody- would anybody disagree that then would become a much bigger spread if we included that number?
0:10:52	student:	Hmm ↑yeah um hmm.
0:10:54	teacher:	Does >anybody< say that it wouldn’t be a bigger spread?
0:11:00	teacher:	>Okay.< So let’s pretend this is five fifty-five and then >so they have< just era:se this two and put five there. (0.4) Would this graph help you see that (0.3) that’s more spread (2.2) out? (0.7) Is there a graph up there that might help let say we did it >let’s say we did to this one< we put five fifty-five right here on the end.
0:11:18	teacher:	Would that >would the graph itself< if you (0.3) could see that or if we did it on this one we had five fifty-five here. (2.9) Is there is there a graph up there that would be better to help you see that spread? than some other ones, and why >would it be< (.) why why would that graph help you see the spread better.
0:11:38	teacher:	Jewel? (1.0) What do ya’ think, yeah go ahead.

Two students, Kerri and Ian, subsequently made contributions that appeared to be consistent with the interpretation that the teacher had in mind. The teacher revoiced both contributions, in the process providing an elaborated reflective summary:

Excerpt 9 [0:14:02–0:15:21]

0:14:02	teacher:	Does anybody not quite understand what Ian is saying?
0:14:07	teacher:	So if we were tah-to
0:14:08	teacher:	((*pointing to Group 3's 10-bin graph shown in Fig. 2.5*))
0:14:09	teacher:	What what he's saying is if we have two fifty here, the next (.) this is two fifty to two fifty-nine, and then it'd be two sixty to two seventy, two eighty to two ninety, and we're-we keep going up (0.7) and how far >would I have to go up< until I got ⌈five-hundred and fifty-five?
0:14:21	teacher:	⌊((*waving hand in direction of the projected point beyond Group 3's graph*))
0:14:25	teacher:	Wally?
0:14:27	Wally:	Um:: (0.6) I think thirty-one times?
0:14:32	teacher:	Ok, what >would the what would the what< would the scale say over here when I got it?
0:14:35	Wally:	Umm.
0:14:37	teacher:	To that part?
0:14:38	Wally:	Five-hundred fifty to five-hundred sixty?
0:14:42	teacher:	Yeah. so we'd have to continue on here to five-hundred and fifty ⌈to five-hundred and fifty,
0:14:44	teacher:	⌊((*extending the x-axis across the board to the right of Group 3's graph*))
0:14:46	student1:	Nine.
0:14:47	student2:	Nine.
0:14:46	teacher:	Ni:ne and then there'd ⌈be a five fifty-five right above it.
0:14:49	teacher:	⌊((*marking a point on the board directly above the projected x-axis*))
0:14:52	teacher:	>Then that then that< then that would look pretty spread out, wouldn't it?
0:14:55	teacher:	>Does anybody< disagree that it would look spread out if we uh (0.9) we had a scale?
0:15:00	teacher:	Whereas on this one, all we'd have to do is, ⌈erase this (0.4) and put a five there (0.3) and we just leave it there right?
0:15:02	teacher:	⌊((*pointing at entry on tabular representation produced by Rene and Janet*))
0:15:07	teacher:	So maybe this one doesn't help you see: how ⌈spread out it is as well.
0:15:09		⌊((*spreading arms out*))
0:15:11	teacher:	Uh (0.7) as ⌈that type of a graph.

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0:15:13 teacher:             ⌊((pointing to the 10-bin graph of
                    Group 3))
0:15:15 teacher:    And like Ian said, so long as you have a scale
                    on the bottom, I think that helps people
                    determine how spread something is.
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Consistent with the transactional perspective, Bauersfeld and Voigt both contended that neither the teacher nor the students have "blueprints" of patterns of classroom interaction. They instead argued that the teacher and students collectively enact particular patterns anew on each occasion, turn-by-turn. In the case of the elicitation pattern, Voigt argued that the students' obligation is to find out what the teacher expects, and the teacher's obligation is to ensure that they learn what is intended. He clarified that this and other patterns are not regenerated in their prototypical form in every instance, but also noted that it is possible to identify regularities in the deviations. He took this as evidence that patterns of interaction are neither automatic rituals nor spontaneous creations. The teacher and students instead regenerate a pattern as they improvise their actions in specific interactional situations in an attempt to achieve what they perceive is expected of them. The notion of pattern of interaction is significant from the point of view of design because leads us to consider what students need to know and be able to do moment by moment in order to be constituted as mathematically competent in the classroom. As Bauersfeld and Voigt note, this knowledge ability is not restricted to what is typically referred to as mathematical reasoning but also includes perceiving both what is expected and whose claims will be honored in particular situations.

Clancey's discussion of tools, instructional activities, and patterns of interaction foregrounds three of the key constituents of classrooms viewed as emergent systems. He attended to a fourth constituent while analyzing the classroom video-recordings when he attempted to determine behaviors that might reveal *classroom norms*. I concur with Clancey's argument analyses of this type are critical from the point of view of design. However, I would push Clancey to take account of norms that are specific to mathematical action and interaction as well as to general classroom norms that might be constituted in science or social studies classrooms as well as mathematics classrooms (Yackel & Cobb, 1996; McClain & Cobb, 2001). An example of a general classroom norm is that students are obliged to explain their reasoning in whole class discussions, whereas an example of a specifically mathematical norm concerns what counts as an acceptable mathematical explanation in a particular classroom. Mathematics classrooms can differ radically in terms of the specifically-mathematical norms that are established, and these differences can profoundly influence the nature of students' mathematical learning, the interests they develop, and the identities they are developing as they engage in (or oppose) classroom activities (Cobb, Gresalfi, & Hodge, 2009).

This caveat acknowledged, the characterization of classroom norms that my colleagues and I have found useful is highly compatible with Clancey's transactional perspective. For example, Clancey emphasizes that norms are not static properties of the classroom setting but are instead emergent phenomena that the teacher and students continually regenerate in the course of their ongoing interactions. In addition, Clancey emphasizes that the relation between individual activity and collective norms is one of reflexivity: Students contribute to the constitution of norms that both enable and constrain their individual activity and learning. This latter contention is pedagogically significant and highlights the crucial role of the teacher in initiating and guiding the renegotiation of the classroom social setting as a primary means of supporting students' mathematical learning.

Clancey highlights a further aspect of classroom systems closely associate with norms when he focuses on humor as an integral aspect of the students' actions and interactions. I found this aspect of his analysis to be both intriguing and enlightening, and can add only one small point that concerns the social nature not just of humor but of emotional acts in general. In doing so, I follow Harre (1986) in noting that "emotion words cannot be the names for [distinct physiological] agitations since it has been clearly demonstrated that qualitatively the same agitation can be involved in many emotions" (p. 8). Instead, as Coulter (1986) clarified, we cannot "identify the emotion we are dealing with unless we take into account how a person is appraising an object or situation" (p. 121). For example, the distinction between shame and embarrassment hinges on whether the person considers that he or she is at fault in a situation. This example illustrates the more general point that emotions have a rationale and are open to justification and criticism. As a consequence, "the causality of internal and external forces becomes irrelevant. Instead of asking, 'What caused me to feel ashamed?' the actor asks, 'What were my reasons for feeling ashamed?'" (Sarbin, 1986, p. 92). Furthermore, the reasons that we give to explain why an emotional act is warranted necessarily situate the emotion in social context by making reference to the local social setting as well as to culture more broadly. As Bruner (1986, p. 117) put it, "emotions achieve their qualitative character by being contextualized in the social reality that produces them." As a case in point, Clancey notes that the students in the video-recorded lessons laughed good-naturedly when the teacher misspoke during a class discussion:

Excerpt 8 [0:28:52–0:29:07]

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0:28:52 teacher:    How did some other people group it? How did
                    Kurt group his? (0.4) Or we can call em the uh
                    special word that they make up at the UW it's
                    called a ben. (1.2) You put things into into
                    a ben? (0.7) Carry it around with you?
0:29:03 student1:   A bin?
0:29:04 teacher:    Yeah a bin.
0:29:05 student2:   ⌈Oh.
0:29:05 teacher:    ⌊Bee eye en.
0:29:06 student1:   >I thought you said< ⌈ben.
0:29:06 student2:                        ⌊>I thought you said
                    ben.<
0:29:07 teacher:    ⌈⌈I probably did say ben but I meant bin.
0:29:07 class:      ⌊⌊Ha ha ha ha ha hah hah.
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Humor was clearly warranted in such situations in this classroom, and played a critical role in the constitution of the teacher's act as one of misspeaking rather than error.

The characterization of emotional acts as socially situated is significant from the point of view of design. First, it indicates that an analysis of the teacher's and students' emotional acts can contribute to the delineation of classroom norms, and vice versa. Second, in contributing to the renegotiation of classroom norms, the students are learning that certain emotional acts are not only warranted in specific situations, but ought to occur (Cobb, Yackel, & Wood, 1989). This indicates the value of the teacher capitalizing on students' emotional acts and framing them as paradigm cases in which to discuss with students how they ought to interpret particular situations. These might include emotional acts that reflect construals consistent with the teacher's agenda (e.g., a student who appears excited after persisting to complete a personally challenging task) as well as emotional acts that are inconsistent (e.g., a student who evidences embarrassment after realizing that she has made a mathematical error in public). In both cases, the teacher uses students' emotional acts as resources to initiate and guide the renegotiation of classroom norms, and thus to support their mathematical learning.

To this point, I have commented on the principle aspects of the classroom setting that Clancey delineates, namely tools, instructional activities, social interactions, and norms together with humor. The value that I see in his transactional perspective stems in part from the fact that this configuration of constituents is relatively close to those on which my colleagues have found it useful to focus when conducting classroom design experiments. I could quibble about the limited attention that Clancey gives to the nature of classroom discourse. I might also push him to explicate the criteria that he uses when identifying classroom norms. However, these are relatively minor concerns that reflect my interests as a mathematics educator. Overall, I appreciate the manner in which Clancey selectively emphasizes aspects of the classroom setting that, in my experience, make a difference from the point of view of design. I also appreciate the manner in which the transactional perspective both acknowledges the complexity of instructional design and problematizes the notions of subject matter content and of modeling. I focus on these latter two issues in the remainder of this short commentary.

Instructional Design, Mathematics, and Modeling

Clancey's characterization of the classroom as an emergent system immediately serves to complicate the process of design by challenging Simon's (1980) famous dictum that if we want to understand the mind, we should study the environment in which that mind functions. For Simon, mind is analogous to jello that is shaped by an environmental mold. From this cognitive science perspective, the classroom setting is treated as existing independently of students' activity and to be composed of independent variables that can be systematically manipulated. Instructional design is then a relatively straightforward matter of specifying classroom molds that have the effect of shaping students' developing reasoning in the desired ways. Clancey dispenses with the notion of independent variables, arguing instead that the constituents of a classroom setting cannot be adequately described apart from the very setting that they comprise. Furthermore, because these constituents include ways of using tools, instructional activities (rather than instructional tasks), social interactions, and norms, the classroom setting and students' activity in it are considered to be reflexively related. As Clancey repeatedly emphasizes, students actively contribute to the continual regeneration and ongoing evolution of the social classroom setting in which they develop particular forms of mathematical reasoning and are developing particular types of identities.

Clancey's characterization of the classroom setting as an emergent system does justice to the challenges of instructional design. For example, it indicates that seemingly minor modifications in any one constituent can have profound consequences. Clancey's observation that the graph paper was constituted as a fill-in-the-blank form rather than as a design tool merely because the students were directed not to write on it until they had created a design is a case in point. In this instance, a minor change in the task directions might have significantly influenced the tool as students used it and thus the instructional activity as they experienced it.

This illustration is paradigmatic in demonstrating the level of specificity and detail that makes a difference in terms of students' mathematical activity and learning. It also underscores that, because of this complexity, instructional designs are rarely realized in the classroom as the designer envisions. In my view, our inability to fully anticipate the consequences of seemingly inconsequential aspects of a design constitutes a compelling reason for conducting classroom design experiments (Cobb, 2001; Design-Based Research Collaborative, 2003; Edelson, 2002). The overriding goal when conducting such an experiment is not to assess whether the design works as intended. Instead, it is to improve the design as informed by coordinated analyses of students' mathematical activity and the classroom setting. It is therefore essential in my view to adopt an inquiring rather than an evaluative orientation when examining artifacts such as classroom video-recordings generated in the course of a design experiment. An observer who has the luxury of reflection when analyzing such artifacts will almost invariably find aspects of the design as it is realized in the classroom that are objectionable. The transactional perspective implies that this goes with the territory. It is critical to move beyond these objections by attempting to understand why students' came to engage in particular forms of activity and not others. Only then is the analyst in a position to propose conjectures about how the design might be improved that can orient inquiry in a subsequent design experiment.

In addition to making the complexity of design understandable, Clancey's transactional perspective challenges the notion of mathematics as subject matter. As he notes, one of the entailments of the subject matter metaphor is that mathematics has the characteristics of a substance. This metaphor is prevalent in discussions of educational improvement that speak of instructional delivery systems and treat mathematics as content that can be placed in the container of the curriculum. Clancey's transactional perspective dispenses with the substance metaphor in favor of the metaphor of mathematics as an individual and collective activity. This latter metaphor orients us to document both the collective mathematical practices established in particular classrooms, and individual students' mathematical activity as they participate in and contribute to the evolution of those collective practices.

One of the issues that my colleagues and I have sought to address while conducting a series of design experiments is that of specifying an analytical unit that enables us to document the mathematical learning of a classroom community over a period of weeks or months. The unit that we have proposed comprises a classroom mathematical practice and students' diverse ways of participating in and contributing to its constitution (Cobb, Stephan, McClain, & Gravemeijer, 2001). In making reference both to communal practices and to individual students' reasoning, this unit foregrounds the reflexive relation between individual and collective activity. A unit of this type is relevant to the concerns of mathematics educators in that it results in analyses that feed back to inform the ongoing instructional design effort (Cobb, 2000). However, I should acknowledge that this construct cuts against the grain in mathematics education circles in that the development of mathematical ideas is typically considered to be an aspect of individual learning that can be adequately accounted for exclusively in cognitive terms. Thus, although mathematics educators usually acknowledge seemingly non-mathematical aspects of the classroom setting such as social norms, they usually think in terms of individual students' learning when addressing what they perceive to be issues of mathematical content. Part of the difficulty is that, for many mathematics educators, the notion of a collective mathematical practice appears to clash with their traditional focus on the diversity of individual students' reasoning. The key issue that needs to be resolved concerns the manner in which communal practices constitute the immediate contexts of action and interaction in which people realize their individuality (Lave, 1991; Wenger, 1998).

On my reading, Clancey's characterization of mathematics as individual and collective activity makes the standard view of modeling problematic. In mathematics education, models are typically characterized as systems of quantitative or spatial relations that can be transformed in prescribed ways. Their primary value is that they enable us to explore the consequences of manipulating the situation being modeled when such manipulations are either impractical or impossible. Two important assumptions underpin this view of modeling. First, models are assumed to originate in and to capture mathematical structures and relationships abstracted from the situations being modeled. Second and relatedly, a clear gap is assumed to exist between the mathematical model and the pre-given, static situation being modeled. These two assumptions make it reasonable to attribute the meaning of the model to associations between the configuration of the models' elements and selected aspects of the situation, and to assess the goodness of fit by focusing on resulting the mapping between the two. Crucially, this formulation of characterizes models in agent-less terms that eschew any reference to from human activity. Clancey's presentation of the tenets of his transactional perspective and his description of his own activity of creating models while analyzing the classroom video-recordings call these assumptions into question.

Clancey challenges the view that models capture structural features of static situations and instead characterizes them in terms of signifying relations that are constituted while engaging in purposeful inquiry. From his transactional perspective, the process of constructing models is not one of abstracting relationships from situations, but instead involves progressively reorganizing activity in and about situations. In developing his account of modeling, Clancey rejects agent-less characterizations and instead adopts the viewpoint of the modeler. As he demonstrates, the apparently firm distinction between the model and the situation being modeled dissolves when the experience of the modeler is brought to the fore. It also becomes apparent that, from this viewpoint, the situation being modeled is not a fixed point of reference that remains immutable throughout the inquiry process. Instead, the model and the situation being modeled co-evolve and are mutually constituted in the course of inquiry. Consequently, rather than portraying modeling as a process of extracting relationships from situations, Clancey characterized it as a process of mathematization that involves reorganizing activity in and about a situation such that the situation being modeled comes to be structured in terms of mathematical relationships.

I drew a similar conclusion that the situation being modeled is not fixed or immutable but instead evolves in the process of being mathematized after I had analyzed students' activity as they engaged in statistical investigations (Cobb, 2002). The students' contributions to whole class discussions in which they presented and critiqued data-based arguments indicated the interpenetration of the model and the situation being modeled. As an illustration, in one design experiment the students analyzed data on the speeds of cars at an accident blackspot (dangerous section of road) before and after a speed trap was introduced. One student commented on the graphs she had created by observing: "Like, on the first one [before the speed trap was introduced], most people are from 50 to 60, that's where most people were on the graph." In speaking of people being on the graph, this student referred to the dots as though they were drivers while simultaneously indicating a feature of the inscription ("are from 50 to 60"). In Nemirovsky and Monk's (2000) terms, the model and the modeled situation were *fused* in her experience even as she remained aware that the dots were not really people. Nemirovsky and Monk go to considerable lengths to demonstrate that fusion should not be equated with confusion. Instead, it is a characteristic of mathematical experience at even the most advanced levels and involves viewing situations through the inscriptions that we have created in the course of the investigation (Polanyi, 1958; Roth, Bowen, & Masciotra, 2002). This process of using inscriptions as texts makes it clear that the inscriptions do not by themselves constitute models. Instead, models are particular ways of reasoning with and talking about the inscriptions (Dörfler, 2000).

Although I see great value in this transaction view of modeling, I also think that it would be a mistake to dispense entirely with the traditional characterization of models as capturing structural relations inherent in situations. I can best clarify the relation between the two views by considering the types of mathematical activity that they take as paradigmatic. Clancey makes it readily apparent that the transactional perspective focuses on the activity of mathematizing a situation in the course of inquiry. In contrast, the traditional view of modeling takes as paradigmatic those occasions when we speak as associationists. This occurs when we step back from the process of inquiry and the activity of mathematizing, and differentiate between the situation-that-has-been-modeled and the model. As Nemirovsky and Monk (2000) observe, we often make this distinction when a breakdown in communication has become apparent and we are attempting to make our reasoning as explicit as possible for someone else. We also speak in this way when we treat the products of our modeling activity as conceptual tools and consider the types of situations in which they might be useful. In doing so, we redescribe the ways that we have structured the situation during modeling activity in terms of a mapping between situation and model.

This associationist view of modeling is an integral aspect of the disciplinary discourse into which we eventually seek to enculturate students. From the point of view of design, this traditional view of modeling therefore contributes to the specification of overall instructional goals by delineating an interpretive stance that we eventually want students to be able to take on their modeling activity. However, this view is of limited value when we attempt to formulate provisional, testable designs that aim towards these long-term goals because it assumes that the situations that are the focus of inquiry have already been mathematized prior to inquiry. The intent of design and teaching then is then to make particular structural features of a situation-that-has-been-modeled salient to students, thereby assuming that they already know at the outset much of what they might learn as they engage in a process of modeling.

Clancey's transactional view of modeling does not deny the associationist experience but questions whether the mappings between models and situations that have been modeled should be taken at face value. From the point of view of design, the transactional perspective orients us to focus not on making particular features of pre-structured situations salient to students, but on how we might support students' progressive reorganization of their activity as they engage in inquiry. In this respect, the contrast between the assumptions that models originate from situations and from activity in and reasoning about situations is a difference that makes a difference for instructional design.

Conclusion

My purpose in this commentary has been to assess the potential usefulness of Clancey's transactional perspective with respect to my concerns and interests as a mathematics educator. In doing so, I have followed Pepper (1942) in viewing ideas as useful to the extent that they give rise to foresight and understanding that enable us to project into the future. In the first part of my commentary, I noted that the transactional perspective provides insight into several constituents of the classroom setting as means for supporting learning. These include tools, instructional activities, social interactions, and norms. These insights enable us to anticipate how classrooms can be organized to support all students' learning of significant mathematical ideas. Clancey's transactional perspective is therefore directly relevant to a central concern of mathematics educators, that of formulating, testing, and revising conjectured designs for supporting envisioned learning processes.

Reflexivity emerged as a central theme in my commentary. Clancey makes it clear that, in his view, the constituents of classrooms as emergent systems are reflexively related and cannot be adequately described apart from the very system that they comprise. This insight both acknowledges and makes understandable the complexity of instructional design. Clancey's focus on the experience of persons as they engage in mathematical inquiry brings to the fore the reflexive relation between mathematical models and the situation being modeled. The transactional perspective therefore problematizes both the metaphor of mathematics as subject matter content and the characterization of models as capturing structural features abstracted from static situations. The alternative view that Clancey develops of mathematics as individual and collective activity, and of modeling as a process of progressively reorganizing activity in and about situations, has far-reaching implications for both design and the analysis of learning processes.

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Chapter 18
Transacting with Clancey's "Transactional Perspective on the Practice-Based Science of Teaching and Learning"

Jim Garrison

Relying extensively on the thinking of John Dewey, William J. Clancey (Chapter 15; also Clancey [1997], Clancey [2002]) has developed an exciting version of transactionalism (with a special focus on inquiry) that he translates into the language of cognitive science and uses to better understand learning in complex contexts such as classrooms and Arctic research stations. While, with Clancey, I cannot sharply separate a transactional perspective on learning in context from social practice theory and dialogic theory, my own work relies primarily on Deweyan philosophical psychology as well as the resources of American pragmatism generally. I am especially interested in the transactional theory of knowing Dewey developed with his collaborator Arthur F. Bentley. I have no background in empirical inquiry; for that reason, my commentary will focus on theoretical and philosophical issues of transactionalism pertinent to Clancey's paper. Since all inquiry is theory (and value) laden, my comments are, hopefully, relevant to empirical inquiry.[1]

My goal in this commentary is to engage in a critical-creative transaction with Clancey in ways that allow for reciprocal growth. I strongly believe Deweyan philosophers such as I have much to learn from empirical researchers such as Clancey who use a plurality of frameworks and are up-to-date on the results of empirical cognitive research. Simultaneously, I believe others interested in devolving valuable learning theories would do well to follow Clancey in appropriating and reconstructing Dewey's ideas and insights, which remain remarkably refreshing and novel in spite of the fact that many of them are now over a century old.

Clancey has evolved his transactionalism for application to contemporary thinking in robotics, cognitive psychology, and computer modeling all oriented toward a better understanding of learning.[2] In doing so, he has not only recovered Dewey's philosophical psychology for the contemporary scene, he has reconstructed it for his purposes, which is something that Dewey, who is known as the philosopher of reconstruction, would strongly endorse. My commentary on Clancey relies on my own more traditionally Deweyan depiction of transactionalism (Garrison, 2001,

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2003), which fails to connect directly with domains of study that have emerged since Dewey's death and has, I believe, undergone little reconstruction, though it still remains my interpretation. While distinct, our two accounts of transactionalism are complementary. In most cases, I will simply elaborate on Deweyan themes and concerns identified in Clancey's paper in hopes of adding depth, breadth, or nuance to his analysis. If successful, my commentary should allow readers to further develop and extend for themselves the ideas contained in Clancey's position paper, along with some I wish to add.

With Dewey, it is always best to begin with a biological organism participating in an environment (or situation) of which it is a *constituent* part; for example, a classroom. Such a beginning motivates "the biological aspect of cognition" and the fundamental failures of the representational theory espoused by artificial intelligence researchers, as Clancey indicates. Living creatures must continuously transact with the rest of existence to maintain the functional coordination (homeostasis) that constitutes their very existence. This fact has several important implications for a transactional understanding of motivation, all of which are at work in Clancey's paper. First, there is no need to motivate living creatures to act; they act by virtue of being alive; motives, including motives to learn, merely redirect action.

The second implication for motivation involves another major theme of transactionalism that derives from its a biological basis. Clancey observes, "Perceptual work is a good example of Dewey's point about the active nature of getting information" (p. 256). This is true because living beings constantly select (and reject) aspects of given situations as they actively *construct*, according to their needs, desires, and purposes, the stimulus-objects, such as graphs, to which they respond. As Clancey indicates, bias is inevitable in any inquiry, which is why, as a good transactional researcher, he acknowledges his bias in selecting aspects of the video situation for the active construction of his analysis and interpretation. The advantage of admitting our biases is that even if we have chosen poorly, others will at least know, literally, where we are coming from.

According to Dewey (1938/1986),"objects are the *objectives* of inquiry," including Clancey and my inquiry (p. 122).[3] Inquirers construct stimulus-objects in the context of a problematic situation for the purposes of transforming the situation to resolve the problem. A fine example of this is Clancey's construction of graphs (Figs. 15.5 and 15.6) as tools that help him better understand the "episodic structure" of the social dynamics in the video. It is a mistake to think the problem resolving stimulus-object exists prior to the inquiry, although other objects constructed as a consequence of prior inquiries are available to the inquirer. Among other things, we must realize that learners always construct the stimulus-objects that motivate them, regardless of what teachers or others may think. It is a mistake, for instance, to assume learners are always constructing the objects teachers intend them to learn. Have a look at Excerpt 3 in Appendix B. Ostensibly, the students are supposed to be using the graphs to co-construct representations that illustrate variability and central tendency. If you look closely at Excerpt 3, however, you will find that the students appear caught up co-constructing all kinds of meaning: whose side will represent the bottom [0:11:20–0:11:46; 0:14:06–0:15:00] and who is the best "eraser" [0:13:22]. Along the way, they advance arguments concerning what may be "easiest" [0:15:46] and most "accurate" [0:16:26]. It is even possible that what is being negotiated is positioning on a dominance hierarchy. In fact, just what stimulus-object or objects (physical objects, abstract ideas, ideals, and such) are being constructed here, if any, are, perhaps permanently, unclear. All meaning constructions are transactional, reciprocally transformative co-constructions. This means that initially the students and teachers are co-constructing the meanings of the graphs in the video, while now we the researchers continue the process.

Obviously, in the activity of learning how to construct graphs portrayed in the video, the graphs should serve as the emerging motivating stimulus-objects, the immediate objectives of the inquiry, and the objectives of learning in this particular lesson. As Clancey points out, however, in this classroom exercise something goes wrong. Clancey chooses to elaborate at length why this happens. I want to explore what goes wrong here in terms of Dewey's transactional theory of motivation as a way of expanding on Clancey's analysis.

Before we can further follow what goes wrong with the graphs as motivating entities, though, we need to expand on the biological basis of Dewey's theory of transaction. Life for Dewey (1925/1981) is not an inter-action between the inside of an organism (e.g., the brain) and the outside environment because "a living organism and its life processes involve a world or nature temporally and spatially 'external' to itself but 'internal' to it's functions" (p. 212). Food, water, mates, tools, language, and cultural institutions are all external to our skin, but internal to our functioning. Functional transactions dissolve the dualisms of internal versus external, mind versus world, or knower versus the known. One way to begin thinking transactionally is to think in terms of biological functions. Early in his paper, Clancey spends a good deal of time sketching a definition adequate for his purposes. If we think of transactions in organic, holistic, functional terms we can fill out Clancey's outline a bit more in ways that should help readers better appreciate what he is up to in his analysis.

Clancey states that "the analysis presented here is a hypothesis, namely that understanding what happens in human behavior, and specifically where and how learning is occurring is facilitated by considering the biological aspect of cognition" (p. 247). Putting aside the "how" question for now, Dewey's transactionalism provides a remarkable answer to the where, while clearly indicating that attempting to isolate learning too precisely is almost sure to oversimplify and distort the analysis. Instead of thinking of actions or interactions performed by simply located substances (e.g., persons and things), transactions are "durational-extensional" to use Dewey and Bentley's (1949/1989) description. Learning is likewise durational-extensional. "If it be asked, 'where' a transaction is located," Dewey (1925/1981) proclaims, "the only possible answer" is that "it is located wherever it has consequences" (p. 156). The same holds for learning transactions. The implications for situated action, much less situated cognition, are clear, we must abandon the notion of simple location. Here I want to draw out some implications for the construction of the motivational cognition that controls situated action.

If there are things external to our existence that are internal to our functioning, then it is no surprise that objects external to the skin provide "internal" motivation. "The identity of self and an act," Dewey (1932/1985) declares, "is the key to understanding the nature of *motives* and *motivation*. Unless this unity is perceived and acknowledged in theory, a motive will be regarded as something external acting upon an individual and inducing him to do something" (p. 289).

It is a mistake to think we have a self that is dormant until something called a motive prods it into action. The self, its actions, and the motives of action are all sub functions of a single functional transaction. In a transactional account of motivation, some supposedly "external" object may prove "internal" to the transaction taken as an organically functioning whole. Further, and this is important for any learning theory, because organic creatures are always already active, in a transaction, we not only express the present self, but, reciprocally, we form the future self. Learning is not occasional; it is constant and unremitting.

An inter-active account breaks down motivation into three parts: a self, its stimulus-objects, and an action, thereby sacrificing analytic clarity and exhaustiveness:

> The term "motive" is thus ambiguous. It means (1) those *interests* which form the core of the self and supply the principles by which conduct is to be understood. It also (2) signifies the *objects*, whether perceived or thought of, which effect an alteration in the direction of activity. (p. 290)

The self and its stimulus-objects are sub functions of a single transaction the agent strives to coordinate through inquiry. Dewey indicates, "Any concrete case of the union of the self in action with an object and end is called an interest" (p. 290). This is precisely what we would expect given the unity of the self and its transactions.

What, we might ask, about the "object" that alters the direction of activity? If we are thinking functionally, and recall the role of interests, then there is a sense in which we can say the "external" object is the motive or cause of action:

> A motive is not then a drive *to* action, or something which moves *to* doing something. It *is* the movement of the self as a whole, a movement in which desire is integrated with an object so completely as to be chosen as a compelling end. Because an interest or motive is the union in action of a need, a desire of a self, with a chosen object, the object itself may, in a secondary and derived sense, be said to be the motive of action. (p. 291)

A student's stimulus-object may redirect and guide action, but it does not initiate it. While external to the skin of our body, a motivating object is internal to our functioning.

Calling the cognitive object (e.g., a graph) the motive is a methodological trope in which a part stands for the whole. This is innocent enough, unless we mistake the part for the whole and thereby ignore the larger context. Only a transactional account of motivation proves entirely adequate:

> It is true enough when we take the whole situation [context] into account that an object moves a person; for that object as a moving force *includes the self within it*. Error arises when we think of the object as if it were something wholly external to the make-up of the self, which then operates to move the foreign self. (pp. 291–292)

Transactional thinking requires us to comprehend the organism-in-environment-as-a-whole; the same holds for mind-(or self)-in-social-environment-as-a-whole. Motivating stimulus-objects (graphs), ideas (graphs as hypotheses of inquiry), and ideals (graphs as the goal of inquiry), provide a telos for establishing a functional coordination of environment and agent as sub functions of a single holistic unity of the transaction. To achieve unity, the agent (the self) must coordinate their activities (responses) with the motivating object (stimuli). The distinction between agent and object is not a distinction of existence, but a teleological distinction of function with reference to reaching an end; i.e., functional coordination or the unity of the transaction.

Understood transactionally, all motivation is internal motivation. So-called external motives (e.g., rewards and punishments controlled by others) distort and deplete the learning experience. When teachers rely on so-called external rewards, learning the subject matter becomes a means to the end of securing the reward or avoiding the punishment. Teaching is an intentional activity. However, when teachers rely on motivating objects outside the subject matter, teaching has unintended consequences. One of these is that students learn to divide themselves such that they conceal private genuine interest in objects of concern and inquiry while feigning interests in public objects that are primarily the concern of authority figures who have the power to reward or punish them for their (in)attention. Such duality of purpose distracts from intense learning, while teaching duplicity and double-mindedness.

In the video, it is clear that the teachers intend the graphs to provide internal motivation for learning, but as Clancey notes, the graphs have become "decontextualized" from the primary inquiry into plant growth; for instance, they fail to function as tools of inquiry (e.g., hypotheses and sources of hypotheses). The numbers plotted on the graph are actual measurements of plant growth, but the numbers seem to have lost all physical meaning and whatever motivational interest may have accrued to the actual process of growing plants and measuring their maturation has departed the pedagogical scene. Clancey remarks that "the inquiry has been moved from the plant domain" where the "numbers have [meaning and] value" to "the graph domain" were the student's are confronted with "a list of numbers and a generalized property called 'spread out' "such that there is nothing "about what the graphs are revealing about the plants" (p. 269). Now there is no such thing as decontextualization per se, there is only recontextualization. Clearly, though, Clancey is right, this recontextualization drastically redirects the inquiry. The graphs as motivating agents redirect action from one domain to another so radically, that the students seem unable to retain continuity between the two inquiries. Thus, whatever interests and objects unified the self regarding inquiry into plant growth are lost to the inquiry into graphs, which the students experience as almost an entirely new inquiry.

Clancey complains, "Plants do get mentioned, but only with respect to 'what's typical,' not motivating the question about plant growth that might be answered by understanding variability" (p. 270). The result, Clancey recognizes, is motivational confusion and a failure to transfer learning from one domain to another. He wonders "whether abstractions would transfer better if they were contextualized in the first place" (p. 270). The transactional answer, of course, is yes. Transactionalism has much to offer study of learning transfer. Because a learning transaction is "durational-extensional," learning will transfer at any time to any place providing the learners pre-existing knowledge can functionally couple with some motivating stimulus-object capable of controlling their action.

Plants and structured prior activities with them are actually spatio-temporally present as potential motivating stimulus-objects, but remain functionally disconnected from the graphing inquiry. The students cease being internally motivated by the plants and the measurement of their growth, although they appear to be quite invested in their dispute concerning how the graph will be constructed. The representation (the graph) and not what it putatively represents has become the topic of the lesson for these students.

Clancey bemoans the fact that in the lessons we see on the video, the "focus is tool-centric as opposed to inquiry-centric. Rather than teaching about the nature of inquiry, the activity is teaching about the nature of graphs." To illustrate his point that "the transactional aspect of graphing has been lost by viewing the graphs as having objective properties in isolation" he presents his own use of graphs as a tool of inquiry for examining the classroom video. He does a good job of showing how graphs emerge as objects of inquiry that both generate and test hypotheses for comprehending the problematic situation presented by the classroom videos. It is easy to expand on Clancey's transactional analysis of graphs as tools of inquiry by building on the functional, organic, and holistic biological understanding already developed.

According to Dewey (1911/1978), tools are living functions. While tools are external to an agent's body they are internal to it's functioning:

> The greatest change of environment occurs when living beings become conscious of the fact that their reactions to preexistent stimuli modify the old forms in such a way as to create new or different stimuli.... This transformation is familiar to us in the form of the tools...by which man consciously modified the environment in the interest of the exercise of his own life activities. In this way, some parts at least of the environment become what have been called "extra-organic" organs; that is to say, all the tools and devices of all the arts, although outside the body, operate in behalf of the functions of life just as do the eye, stomach, hands, etc. From this biological point of view, deliberate or conscious behavior is just a way of doing more effectively and economically what unconscious life adaptations do in a relatively wasteful and uncontrolled way, namely, modifying the environment so as to make it a more varied and more stable or secure stimulus for the exercise of functions. (p. 439)

Understood transactionally, tools are neither simply internal nor external to anything. Tools emerge when body-minds can creatively use environmental resources to retain those responses that coordinate with preexistent stimulus-objects in such a way as to constitute new or different stimulus-objects. Using one set of stimulus-object to infer another marks the emergence of embodied inference and means-ends inquiry.[4]

Organic-environmental adjustment at all levels is an emergent transaction resulting in "new environments just as truly as new organs" (p. 438). Here we are concentrating on the emergence of new organs (tools such as graphs) for transforming the environment. Dewey (1913/1978) writes:

> Tools may be regarded as a sort of extension of the bodily organs.... *It is the discovery and use of extra-organic tools which has made possible, both in the history of the race and of the individual, complicated activities of a long duration* – that is, with results that are long postponed.... The use of tools and appliances (in the broad sense) also demands a greater degree of technical skill [techne] than does mastery of the use of the natural organs – or rather, it involves the problem of a progressively more complicated use of the latter – and hence stimulates a new line of development. (p. 188)

Once produced, tools such as writing, mathematics, and graphs become the instruments of future inquiry. Learning to use tools transfers development from a strictly biological to a linguistic and cultural domain.

For Dewey, all inquiry is means-ends reasoning. Tools are mediating instruments (means) of inquiry. It is possible to make a tool an end in itself, but that is to redirect the inquiry. In the classroom lessons portrayed in the video, the graphs become an end in themselves in such a way as to seem, to the students at least, completely detached from the inquiry that preceded it. The graphs do not function as tools; they are not internal to the students' inquiry and they are very far from functioning as extra-organic organs.

Understanding the transactional nature of Dewey's instrumental, means-ends theory of inquiry allows us to develop a deeper logical, epistemological, and even metaphysical insight into Fig. 15.1 in Clancey's paper and why he claims that from a traditional cognitive modeling perspective, the notion of transaction is a non-linear conception of causality, though I wonder if even Clancey is prepared to take this claim as far as Dewey does. Clancey is right, causation is not linear for Dewey; in part, though, that is because for him, causation ceases to be an ontological category altogether. One way to see this circularity perhaps is to realize that there are not causes without effects. In a sense, the effect is the cause of the cause. What is really at stake is functional coordination of the whole situation. The cause is just that aspect of the whole situation the inquirer identifies at most critical to achieving coordination. In fact, the entire situation is constituted by perhaps an infinite number of converging events. The cause is merely an aspect of the whole situation that the inquirer attends to, is most interested in, alters, or acts upon. For Dewey, causality, necessity, and even essences are all products of inquiry, something that emerges in means-ends coordination; causation too is an objective of inquiry. In other words, causation, etc. is logical not ontological.

To understand Dewey's theory of causation, we must comprehend some of the more remarkable properties of his theory of means-ends reasoning. First, there are no ends until there are means or means until there are ends. Likewise, there are no causes until there are effects and effects until there are causes. Means and ends (cause and effect, necessary and contingent) are simply sub functions of a larger function constituting a coordinated situation. Second, means constitute ends just as ends constitute means. Third, a given existential situation is simply what it is; the distinction of means and ends, cause and effect, necessity and contingency is purely "teleological," by which Dewey means, a distinction dependent on the purposes of the inquirer.

Chapter 22 of Dewey's (1938/1986), *Logic: The Theory of Inquiry* (the subtitle tells you what Dewey means by the word "logic"), titled "Scientific laws – Causation and Sequences" is crucial for our purposes here. Everything that is a *constituent* of an existential event, say a death by murder to use Dewey's example, is necessary for that event to occur. To pick out any one thing as the antecedent cause is simply to express that for the inquirer's purposes something in the situation is especially important. In legal inquiry, we convict someone of murder by showing that they are among constituents of an event (i.e., a death). In truth, an infinite number of events constitute a situation (which is why Clancey is wise to confess his bias in selecting from the situation depicted in the videos). The bullet from the gun must strike the target with sufficient force; the target must be a vulnerable part of a human body; the society must have a concept of murder as well as laws against; it, and so on forever. Ultimately, Dewey draws,

> . . . the theoretical conclusion that causation as ordered sequence is a *logical* category, in the sense that it is an abstract conception of the indefinitely numerous existential sequences that are established in scientific inquiry. . .. for when events are taken strictly *existentially*, there is no event which is antecedent or "cause" any more than it is consequent or "effect." (p. 453)

Later in the same chapter of the 1938 *Logic*, Dewey explicitly states that "the category of causation is logical, that it is a functional means of regulating existential inquiry, not ontological" (p. 456). Dewey drains many things from the ontological realm of metaphysics into the domain of logic by showing they are the product of purposefully driven inquiry on the part of finite and impassioned creatures.

Decades earlier, Dewey (1893/1971) relied on his means-ends analysis of inquiry to draw the same conclusions about causation: "We call it 'means and ends' when we set up a result to be reached in the future. . .we call it 'cause and effect' when the 'result' is given and the search for means is a regressive one" (p. 36). This conclusion actually derives from his analysis of necessity:

> . . . Contingent and necessary are thus the correlative aspects of one and the same fact. . .. Contingency referring to the separation of means from end. . . necessity being the reference of means to an end which has still to be got. Necessary means needed; contingency means no longer required – because already enjoyed. (p. 29)

In the 1938 *Logic*, Dewey draws a strictly similar conclusion regarding the notion of an essence, "Anything is 'essential' which is indispensable in a given inquiry and anything is 'accidental' which is superfluous" (p. 141). Elsewhere, Dewey does the same for stimulus and response (see Dewey, 1896/1972). Coming to grips with Dewey's theory of inquiry will require researchers to completely rethink their fundamental methodological and ontological categories in ways that are not likely to happen soon. Nonetheless, radical re-conceptualization is what is required if the reader really wants to understand what Clancey is actually getting at in Fig. 15.1 of his paper.

Let us now consider the issues surrounding the following: "Putting our representations into shared space." The teacher's "virtual modifications of the graphs, revealing that imaginary objects may also be shared" particularly intrigues him. I would like to comment on Clancey's observations that primordially, on a Deweyan transactional account, all representations are shared, hence all representation have a residual, objective, public component. To adequately comprehend the transactional character of a representation is, for Dewey, to come to comprehend the functional, distributed, durational-extension nature of the mind itself.

Intentionality is the criterion most used to distinguish "mental" activity from other forms of action. The word derives from the Latin *intendo* signifying to "point" or "aim" at, or "extend" toward something such as gesturing toward a graph or another person, or even along imaginary axes. Intentionality is not a psychic substance; rather it involves "aboutness" and "distal access." Intentionality involves the ability to grasp meanings, including tools and language. Like any living function, meanings are not simply located, and to have a mind is to have meanings; that is, to be able to deploy representations. Dewey's (1922/1983) understanding of *cognitive* functioning is powerful though pedestrian:

> But a thing which has or exercises the quality of being a surrogate of some absent thing is so distinctive, so unique, that it needs a distinctive name. *As exercising the function we may call it mental*. Neither the thing meant nor the thing signifying is mental. Nor is the meaning itself mental in any psychical, dualistic, existential sense. . .. A probable rainstorm, as indicated to us by the look of the clouds or the barometer, gets embodied in a word or some other present thing and hence can be treated *for certain purposes* just as an actual rain storm would be treated. We may then term it a mental entity. (pp. 56–57)

Mental functioning, the construction of representations, emerges from physical and biological functioning without breach of continuity.

J. E. Tiles (1995) explicates Dewey's theory of mental functioning using the example of a barometer; he could have used a graph. Someone who knows how to "read" a barometer, and notices it has fallen, may grab a raincoat as they leave home. Tiles writes, "What is mental is *the way* the barometer indicator *functions* to influence. . .. actions" (p. 143). Meanings, including tools such as barometers and graphs, have a double life; they physically exist but they perform a representational function when some agent can take and use them for a purpose. Clancey wonders for what purpose, if any, the students in the video can take and use graphs. Meanings always purport to refer. The word "barometer" spoken or written is a meaning that refers to weather. The graphs in the video refer to plant growth. The way they are decontextualized, however, deprives them of their primary reference, which is why the students became confused and their minds wander.

A barometer or a graph alone is not a representation, but a sub function of a three-term representational function that includes the referent (weather conditions or plants) and some aspect of the agent (their brain or some such). Most theories of representation, including Vygotsky's and that of traditional artificial intelligence researchers, assume a two-term schema where something mental is stored *in* and retrieved from consciousness, the mind, or memory, and which refers to something not mental *in* the world. Adherents to the two-term schema must then use some theory of correspondence, or dialectics in Vygotsky's case, to handle the dualism. As Tiles indicates, in a three term meaning function, "we have a subject or agent whose act is to take [or make] something beyond itself as referring to something else beyond itself" (p. 144). Tiles depicts the typical schema; obviously it is possible for either or both of the second two terms to function reflexively. A three-term schema makes mental functioning a durational-extensional event in a "world without withins," as Tiles describes it. To study the transfer of learning in a world without withins, we must attend to both the functional properties of the agent and the functional properties of the situation to which we expect the agent to transfer their mental abilities. The mistake of most theories of transfer lies in confining mental functioning to the agent's consciousness, brain, and the like.

Dewey's three-term representational schema is an extension of Charles Sanders Peirce's three-term semiotics. For Peirce (1868/1992), "We have no power of thinking without signs" (p. 30).[5] Consider the following three-term definition of "sign" from late in Peirce's (1907/1998) career:

> I will say that a sign is anything, of whatsoever mode of being, which mediates between an object and an interpretant; since it is both determined by the object relatively to the interpretant, and determines the interpretant in reference to the object, in such wise as to cause the interpretant to be determined by the object through the mediation of this "sign." (p. 410)

This passage depicts a three-term representational transaction involving sign, object, and interpretant as sub functions of a single semiotic function. An interpretant is any sign that serves to interpret another sign. I want to concentrate on embodied interpretants.

Peirce identifies three kinds of embodied interpretants all of which occur in Clancey's analysis. The first is the "emotional interpretant" (p. 410). The second is "dynamical action" or activity (p. 411). The third regards "the *ultimate* intellectual interpretant" which, Peirce concludes, "are habits" (p. 431). Neurophysiological habits are generalized rules of action in that they are predispositions to respond to the same or similar stimulus-object in the same or similar way; as such, they are distinctively cognitive. They are, however, only one part of a three-term representation. In addition, if we do not confuse the interpretant with the interpreter, it is possible to understand how someone can hold contradictory beliefs and feeling regarding what it means to make a graph.

In a three-term semiotic, the neurobiological (or neuropsychological) sub function of representation (e.g., the brain) may have no structural similarity to the signifier or signified sub functions. That means it need not copy or epistemologically correspond to its referent; all the neurobiological function must do is transactionally *coordinate* with the other two sub functions (i.e., the sign and signified) of the meaning function. Once we realize this fact, we can see the importance of Clancey's ideas about perceptual and conceptual categorization. They allow us to update the pragmatic notion of habits.

For those creatures with the requisite neurobiological endowment, the ability to construct representations originates in social transactions such as we see in the video. The fundamental act of meaning making for Dewey occurs when two emergent agents co-designate an emergent object (e.g., the meaning of a graph) between them by responding to the object from the standpoint, attitude, and actions (e.g. gestures) of others. In other words, all representations initially emerge into a shared space.

The basic idea is one of means-ends coordination wherein each emergent agent must take the other emergent agent and use them as a means to the end of determining an emergent object. Initially, they may substitute responding to each other here and now as they will to the object later. Likewise, to have a self is to respond to one's own actions from the standpoint, attitude, and actions of others. Actually, we acquire social stimulus-objects before we acquire physical stimulus-objects.[6] Eventually, social transactions involve forming a general rule of action in the form of a habit or even a rule on the classroom wall. The whole point of the lesson portrayed by the three videos that are the focus of this book is for students and teachers to arrive at a shared interpretation, habit, or rule for constructing and responding to graphs.

Minds, selves, and things are all primarily transactional social constructions. In any social transaction, the meaning of the two agents, as well as the stimulus-object they strive to co-designate, undergoes transformation. There is an important pedagogical point here, when we teach well, we will find the meaning of the subject matter changes for us as well as our students.[7] Transformations always accompany transactions. Here is an important question: "In an interpersonal activity, can we understand the classroom practice without understanding their personalities?" The answer is clear; we cannot entirely understand the meaning of any social practice or dialogical encounter until we can understand the emotional and cognitive attitudes that shape the transformative transactions of socially constructed things, minds, and selves. I might add that the same remarks hold for how we shape and interpret each other's actions regarding the videos that are the focus of this book.

Dewey developed the basics of his theory of the social origin of mental functioning in close collaboration with his friend and colleague, George Herbert Mead, though Mead worked it out more thoroughly. The notion of a conversation of gestures, taking the attitude of the generalized other, and the active constitution of stimulus-objects is readily visible in the videos. The conversation of gestures includes bodily gestures such as pointing, facial gestures such as smiling, and laughter. Clancey refers to many such gestures in his commentary and selects photographic stills that are clear instances of pointing and facial gesturing. In the case of the teacher pointing, we have rather transparent examples of the teacher serving as a sign for which the graphs (and even imaginary line on them) are the signifieds, presuming the students are attending and have the proper interpretant. Vocal gestures, for example, words, are especially important because agents may respond to their own such gestures as others do. Self-reflexive representation allows us to take the attitude of others in responding to our own acts in functionally coordinating with stimulus-objects in the world. We would not gesture to ourselves unless we first gestured to others. As Clancey indicates, the sound quality of the videos is good, so we have plenty of clear evidence of vocal gesturing toward others, and many instances of participants vocally gesturing toward themselves (e.g., students and teachers "calling" attention to themselves and even showing off).

Dewey, like Ludwig Wittgenstein, rejects the private language argument. One of the most preeminent American philosophers of the twentieth century, W. V. O. Quine (1969), remarks that both Dewey and the later Wittgenstein were "semantic behaviorists."[8] Behavioral semantics, according to Quine, involves "knowing how to use a word" (p. 28). What I would prefer to call activity semantics abandons "the myth of a museum in which exhibits are meanings and the words are labels" (p. 27). Meanings emerge in social transactions; Clancey comments that there are no "fixed, pre-determined objects" (p. 261). In Wittgenstein's famous slab game, those who can eventually respond correctly to the behavioral gestures of others (e.g., pointing, saying, smiling) learn to become members of a sociolinguistic community of practitioners, bricklayers perhaps; those who cannot respond correctly must join other communities. We may say the same for the graph game wherein participants "put out representations in shared space."

Quine explains that if we follow Dewey into a "naturalistic view of language" and a "behavioral view of meaning" we must not only abandon "the museum figure of speech," we must "give up an assurance of [semantic] determinacy" (p. 28). The title of Quine's famous essay from whence I have been citing is "Ontological Relativity." We cannot ever eliminate the semantic under-determination of ostensive gestures. The possible meanings of an actor, act, or stimulus-object are always infinite. The graph paper given the students provides an especially pellucid example of what Clancey calls "representational change" arising in the process of problem solving. Here the task is to parse the simultaneously structured yet empty spaces provided by the graph paper. The teacher's see only one, or a few, possible meanings, while the students, rightfully, see a plethora. Many problems of teaching and learning occur in precisely such problematic situations and involve semantic under-determination as well as the need for the *negotiation* of meaning because sometimes teachers cannot simply tell the student the "truth." Only someone who thinks teaching and learning is information processing would believe that is possible.

Clancey's comments about "perceptual work" and how "turning a representation leads us to interpret it differently," illustrates Quine's point perfectly. This semantic under-determination is present in every interpretation of the videos constructed by the participants in this conference. That does not imply, however, that our community may not come to some consensus in its efforts to co-designate the emergent people and objects in the videos among our various emergent centers of semantic action that we call position papers, commentaries, and discussion papers, though it will be difficult.

Clancey wonders: "What does laughter and play suggest about classroom practice, relevant to designing educational activities and evaluating learning?" (p. 256). I am impressed that Clancey would emphasize emotional experiences as crucial pre-conceptual organizers that facilitate functionally coordinated group activity. Emotional states are often the signified of facial gestures that are signs for those agents who have the requisite interpretant. That is to say, emotional states and their facial correlates often become sub-functions of sign functions, representations, and concepts. We must work out the meaning of emotional gestures, including humorous comments, just as we would any other kind of gesture; that is, by analyzing social transactions. Clancey is correct; they are not self-acting traits of persons or stories.

There is something else remarkable about Clancey's treatment of emotions. Clancey emphasizes positive emotions such as humor as an attitude toward situations and those in them, and connects such emotions to imagination and creativity. Almost all work on emotions, including my modest efforts, emphasizes negative emotions like fear and anger. Interestingly enough, recent research on positive emotions (see Fredrickson, 2001 and others) has confirmed Clancey's conjecture that positive emotions, and signs of positive emotions, in fact, do facilitate creative individual and social action. The social construction of emotions is a promising domain of study for theorists of situated transactions, including those who pursue research agendas in situated cognition, activity theory, and dialogical learning.[9] I found his transactional analysis of humor original and engaging.

Although I cannot add anything to Clancey's fine analysis of humor, I would like to supplement it with a more complete transactional account of emotions in general (see Garrison, 2003). I want to briefly discuss the meaning of facial gestures, or what are misleadingly called emotional expressions. A longer discussion would rely on distinguishing brain functions in ways that closely resemble Clancey's distinction between perceptual and conceptual categorization. A smiling face is a gesture most agents in every culture can take and use as a sign that signifies a positive emotional state. The ability to properly interpret emotional gestures is crucial to functionally coordinating social behavior, especially in small spaces such as classrooms, space capsules, and Arctic research stations, including being a useful "way to handle conflict," as Clancey indicates.

A common mistake is to assume emotional gestures are emotional expressions. The research of Paul Ekman (1973) has established that adult members of all cultures can usually identify sadness, anger, and fear from photographs. This pancultural consistency seems to prove emotional expression is innate, but it does not. What it proves is that the autonomic nervous system (ANS) is the same in all human beings and that the muscles of the face have a very narrow range of possible configuration. Because "reading" emotions are so immensely important, almost everyone *learns* to properly interpret these facial gestures. Further, agents must learn to find certain things funny and other things fearful; the objects of fear and humor are not innate. Once we learn to take the attitudes of others with regard to our own gestures, we may even learn to put on a happy face for them even when they are sad. Professional actors make careers of disconnecting affective signs from the emotions they denote.

Consider this counterexample. The eyes of *Homo sapiens* dilate when they are excited; it is an inherited ANS reflex. That does not mean individual *Homo sapiens* intend to express excitement, only that others may learn to interpret the gesture of dilated eyes as such an expression. If we are playing poker, I draw a card, suddenly bet everything, and my eyes dilate, it does not mean I intend to express something. If you know how to interpret the signs correctly, however, I may nonetheless communicate something I would rather conceal. Almost everyone in any culture will learn to read facial configurations if they learn to coordinate their social transactions at all well. That means they must learn to interpret the facial gestures of others. Since we inherit some of these facial configurations, it is not surprising that the interpretation of some emotions such as anger and happiness are pancultural.

Notes

1. I would add that all theories and values are contingent upon empirical consequences. The result is a transactional hermeneutic circle wherein theories and values influence empirical findings and empirical findings influence theories and values. This insight takes us to the core of Dewey's theory of reconstruction.
2. We may readily read Dewey's theory of inquiry as a theory of learning that replaces the need for epistemology altogether (see Shook [2010]).
3. Nowhere has emphasis been added to quotations.
4. For Dewey, formal acts of logical implication come later.
5. Signs are living meaning functions constituting our very capacity to think, Peirce (1868/1992) concludes:

    > But since man can think only by means of words or other external symbols, these might turn round and say "you mean nothing which we have not taught you, and then only so far as you address some word as the interpretant of your thought." In fact, therefore, men and words reciprocally educate each other; each increase of a man's information involves and is involved by, a corresponding increase of a word's information (p. 55).

    It is much easier to understand this claim if we think of signs as extra-organic organs that may have unintended transactional consequences for the agent who creates them.
6. See Mead (1934/1967) and Hans Joas (1985, Chapter 7).
7. See Dewey (1916/1980, p. 8). Teachers who are alive to this fact are less likely to burn out because they experience their teaching selves as continuously growing.
8. Rorty (1979) considers both these former schoolteachers to be "epistemological behaviorists"(pp. 136 and 176).
9. For Dewey (1916), both work and play are guided by ideas and ideals about the ends of action; the difference is that in play the ends of action are freer and more plastic. There is a great deal of depth to Dewey's observations that all ends should remain internal to the activity:

    > Work is psychologically simply an activity which consciously includes regard for consequences as part of itself; it becomes constrained labor when the consequences are outside of the activity as an end to which activity is merely a means. Work which remains permeated with the play attitude is art. (p. 214)

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Chapter 19
Making Sense of Practice in Mathematics: Models, Theories and Disciplines

Jere Confrey

In responding to William Clancey's paper "A Transactional Perspective on the Practice-Based Science of Teaching and Learning" and reviewing the videotapes from Richard Lehrer and Leona Schauble's project, I sought a stance that would permit me to bridge from theory to practice, from the general to the specific, from the abstract to the contingent. In addition, in order to contribute to the theme of the meeting, conceiving of a program of studies for a practice-based science of teaching and learning, I chose to consider the issues of the role of disciplinary or content knowledge on the interpretation of the episodes and its potential relationship to Clancey's transactional theory.

Clancey's theory of transaction seems to be intuitively well-founded, and we share roots in a number of common theorists. The theory seems compatible with constructivism, particularly radical constructivism (von Glasersfeld, 1991) in which the emphasis not only on the importance of student action and activity in learning but also on the "contingency" of knowledge based on the inability of humans to "transcend" the gap between what is known by knowers given their perceptual apparatus and experience and some external reality. His emphasis was thus on the fit of our theories of the world, rather than on their match with external conditions. Clancey labels this as "transaction" contrasting it with interaction which "concerns how traits interact, giving rise to observed properties, rather than how behaviors are improvised, emergent, and dynamic within a developing situation" (p. 251). Within this tradition, a number of theorists have stressed how instruction transforms its participants, both students and teachers (Confrey, 1990a; Steffe & Thompson, 2000). Likewise, Clancey writes, "The subject matter…is not merely presented, exchanged, digested, and tested, but is (potentially) transformed in the understanding of the teachers as well as the students" (p. 249).

Further, transactional perspective is linked to pragmatism with roots in Dewey, who responded to the influences of James and Pierce. For the purposes of my comments, the pragmatist roots permit one to ask, in very fundamental ways, in what

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sense is the activity itself grounded in the application of cultural tools or descriptions of physical regularities as the actor works to resolve problematics. Finally, the theory draws from what Bateson referred to as the second cybernetics, where cybernetics applies itself to social science (Bateson, 1972). Thus, the work of von Glasersfeld, von Foerster, Maturana, and Bateson all take the view that knowledge derives from action accompanied by feedback and reflection. That is, feedback and reflection are not additional elements but that these bootstraps, these catalysts of distinction and boundary, are what create, sustain and propel forward the identity of the individual, the group, and the context. Clancey's intent, to connect the perceptual-motor as conceptualization (Dewey's inquiry), the affective as orienting (Bartlett's remembering), and the neuropsychological aspects of conceptual systems, has promise as it is to be applied to the classroom episodes.

The question I would pose, as a mathematics educator, is "does this theory lead Clancey to identify the critical elements in those episodes for the development of a science of teaching and learning?" To answer it, I selected what appeared to me as key issues in the classroom episodes and compared them to Clancey's analysis. The three episodes he selected addressed topics of: (1) perceptual work on sharing representations, (2) playful attitude and students' emotional states, and (3) purposeful context in relation to abstract views of math. If one assumes that theory is meant to be a guide; a lens by which one sees and draws distinctions, then the usefulness of a theory of praxis lies in what it permits and encourages us to see. By comparing and contrasting these two selections, I am not implying that his selections and mine should be congruent, but only evaluating, for myself, the extent to which his theories point to the kind of issues of most salience to me professionally.

As a mathematics educator, my priority commitment in examining practice is typically focused on searching for three elements: good content, engagement by children, and the potential to help schools improve the teaching, to engage students in productive learning of good content. I am not so much interested in studying how it works, but in studying how it might work if the practice is reconstituted in interesting ways – what Lehrer refers to as "working in a design space." While these three elements may seem a narrow focus (too schoolish) or too evaluative (linked explicitly to reform), they are driven by the very real fact that success in mathematics is a gateway to many other opportunities in our culture, and that failure exacts a high price from students in our educational system (dropping out, failing to graduate). Secondly, I am interested in what I, and others, call "conceptual corridors" (Brown, 1992; Lehrer & Pritchard, 2002; Confrey, 2006). As students learn more and more complex mathematical ideas, there are patterns in the sequence of ideas that are generative of solutions to the types of problems we can solve. While any particular class's route yield a particular "conceptual trajectory," within which each student's trajectory may differ like strands in a rope, a conceptual corridor refers to a overall description of a wider pathway, containing constraints, landmarks and warnings that will make the transition from novice to expert more likely to be successfully achieved, and hence provide instructional guidance to teachers.

That said, I will proceed to identify three key issues that this perspective led me to observe, and then return to the question of the applicability of Clancey's theory to a science of practice. The three key issues were: (1) the role of competing conceptions, (2) typicality and bin size, and (3) variability, predictability, and spread.

The Role of Competing Conceptions

As I watched the episodes, most notable was the intensity of the competing conceptions initially experienced by students. From the literature on misconceptions and alternative conceptions, we know that epistemological obstacles (Confrey, 1990) do not evaporate, but must instead be confronted and considered, and alternatives must be seen and chosen. Otherwise misconceptions are suppressed and the work becomes procedural or the beliefs re-emerge at the next possible instance.

We also know from this work that what often appears to be a misconception has compelling aspects that are also correct, in either a restricted or alternative framing. Examining this aspect requires one to permit the emergence of the alternative and to evaluate what it does accomplish. In the main, there are two competing approaches by students in Clancey's examples. They are displayed in Fig. 19.1. In the first panel, there is some representation of the scale of possible heights and a frequency chart or histogram is built. In the second, the plants are ordered by height and then the heights are displayed along the vertical axis. The third (Fig. 19.1c) is a representation that I will discuss subsequently.

I concur with others that many more students might have drawn the second representation, if not for the intervention of the research staff in a rather heavy-handed way. They, of course, are likely to know context and history to which we do not have access. My guess is that they entered with the expectation that the students would produce histograms relatively easily, or at least form some kind of representation of the aggregation of the data. This would permit the instructors to focus their review on typicality, and enter into an instructional discussion on spread. As is often the case in instruction, when a plan encounters unexpected and persistent resistance, it takes time for an instructor to recognize it and respond.

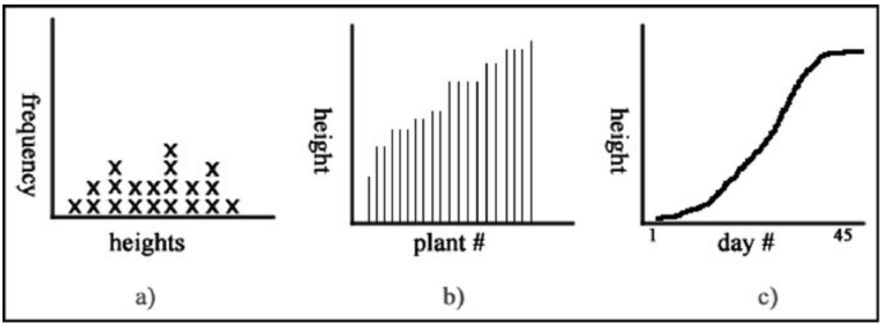


Fig. 19.1 Multiple representations of a sample of plant heights

As the students demonstrated (and were supported in doing so), the first representation can be used to answer the questions of typicality to some degree, and hence it satisfied the students' immediate goal. By the way, it is instructive to pay attention to Lehrer's repeated question in the group, "how does it [plant number] help you: answer your question?" [Excerpt 5, 0:41:05]. While I suspect this question reveals an expectation for a histogram, his persistence in linking question and answer creates the space for the boy to build his stem and leaf, and is a nice example of instructional guidance and support for diversity in approach. I see these episodes as early ones in establishing a sense-making norm in the classroom, strikingly absent in many mathematics classes.

The plant height vs. the count may be viewed as a more primitive approach, in that it permits the students to avoid struggling mightily with scale on the *x*-axis. Once the plant heights are ordered, a scale on the *y*-axis is needed for marking heights, which is an easier task than creating bins (which is a reference to how students create the intervals used in their histograms). In addition, the plant height's display is iconic, which helps the students to proceed. With this iconic mindset, the idea to represent (distribute) the values (as heights) on the *x*-axis is much more challenging to the students [Excerpt 5, 0:41:25–0:41:47] and requires a cognitive shift in perception. That is, the histogram requires students to separate the frequency from the value of the height. This requires the students to use a spatial second dimension to represent a count or an index, which is itself dimensionless.

Lehrer refers to dimensionality himself in an interaction with a student, where he says, "Do you need two dimensions to show how spread out they are or could you do it with one?" [Excerpt 6, 0:51:00]. I would suggest that in an odd way each of the two competing graphs are, sort of, one and a half dimensions. They are not one-dimensional like a number line but they are also not representing covariance between two variables (i.e. scatter plots of height and width). Referring again to Fig. 19.1, the left representation is a histogram, in which the values are scaled on the horizontal axis while the vertical axis is a count (a dimension), but it also a bit like a scalar, hence the "half" dimension. In the second case, the vertical axis is height, but the horizontal is an indexing of the position of the plants when ordered from small to large, again a half dimension. Compare these to what the students may have been thinking about, which is the prediction of height as a function of time, in which one sees a graph as a form of a trend line, as represented in the third frame. Here, we note there is scaling, beyond ordinal relations, on both axes.

This movement from ordinal spacing to interval spacing (or ratio scales if zero means zero) is more difficult than many people realize, based on my research. As I watched this part of the class video, I recalled a teaching incident in which sixth grade students were asked to put a set of dates of major events on a timeline, ranging from the Big Bang to the present. Initially the students simply wanted to order the events and the corresponding dates (some of which were in scientific notation) next to each other. We realized that while they had read number lines, they had little experience building them. Our conjecture was that for them, there was no differentiation between the values on the *x*-axis and timeline itself (or scale). That is, the ordered events *were* the scale. Likewise, for the class on the videotape, the plant numbers, after being ordered by plant height, comprised a scale. This is an ordinal scale, not an interval or ratio scale (recall nominal, ordinal, interval and ratio scales). Thus, the researchers have a second challenge in addition to the one of the "part-dimension," namely, how to separate events from their placement on a scale (or form of number line).

My interpretation was that the researchers were encountering how conceptually challenging this transition was for the students in two respects, and it was difficult for them to de-center to interpret, diagnose and generate potential solutions. An essential part of a design study is to recognize when this happens, and to consider alternative interpretations of the students' actions. It is also necessary to consider how to address that challenge: first to respond in real time, then to respond as a research team in preparation for the next few days, and finally, to interpret the outcomes after the experiment itself is complete. Design research requires investigators to simultaneously carry out descriptive, explanatory, and prescriptive sets of activities. In future work, Lehrer and Schauble might consider the possibility of including a number line activity earlier in the curriculum to facilitate resolution of the two challenges facing the children.

Furthermore, the contrasts between the first two representations in Fig. 19.1 could be used as a means of facilitating an interesting discussion that could produce sensitivity to these distinctions on the part of the students, and a broadening of their ideas of graphs. Here I agree that what is valuable is to catalyze and harvest variation, and to see that each graph brings forth, hides, and distorts in some ways. This appreciation is what Andy diSessa calls "meta-representational competence" (diSessa, 2002).

To see an illustration of meta-representational competence, consider how the first two representations in Fig. 19.1 relate to each other. If one rotates and flips the plant number vs. height graph to project the heights as horizontal bars, and then forms bins below, on the vertical axis, and imagines a dot representing the heights of each plant fall into bins, you can produce the link between these two (see Fig. 19.2). In

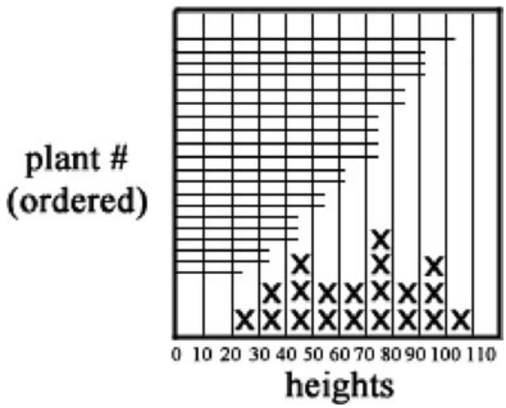


Fig. 19.2 Relating competing representations

my experience, one way to assist in reconciling competing relations is to create a super-ordinate relation in which one can see how the two relate to each other.

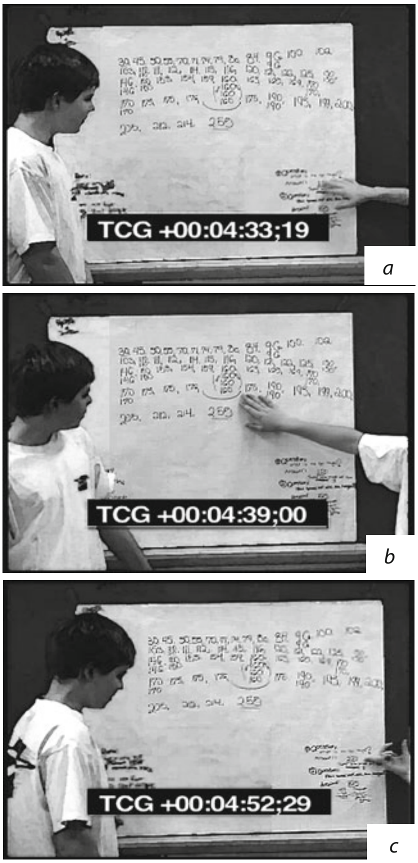
Typicality and Bin Size

Throughout the exchange, we see interesting transactions, as the students respond to the request to discuss a typical plant on Day 19. Repeatedly, we hear students reporting on the value that was most commonly repeated which would be the mode (most common value) of a histogram of bin size one. What is sometimes confusing to people is that if you change the bin size, you change the typical answer. Most people recognize that changes in bin sizes result in changes in distribution as shape, but they also expect it to change in ways that maintain some amount of "similarity" (as a mathematical term, same shape, different size), which is incorrect. I recall that working with dynamic statistical software and stretching the axis dynamically and witnessing this. Imagine stretching the distribution that Schauble's group worked with, and consider all the distributions shown that are possible, as bin size changes. This demonstrates that mode as a measure of central tendency is not necessarily resistant to changes in scale or bin size. It appears to me that this raises another conceptual issue, typically overlooked by teachers and curriculum designers and researchers. The selection of bin size is a judgment, not an algorithm, and will affect the reasoning about distribution to the extent distribution or typically is based on mode, which seems to be the dominant interpretation for typicality, although mean and median arise secondarily.

What strikes me as important, as a result of this analysis (and, actually, others that I have done with my own research on practice), is that it is the issues of invariance and sensitivity that are particularly critical here for students. That is, a reason for selecting the median is that bin size is irrelevant as the median involves the count of the numbers not their relative location. Box plots with quartiles have this same sort of resistance. But note, as we move to count the number of data points, regardless of their relative size, we have a very different meaning for grouping, based on count and not on some sort of natural breaks in the values.

The mean is valuable as it takes into account each and every value and its relative size. These ideas lurk behind the student comments. One group discusses them explicitly in procedural terms, yet they are not very carefully brought out conceptually during the discussion. Typicality becomes tied to the representations, and so the focus is on bringing forth and explaining the representations, with typicality taking a back seat. The problem is that data that are clumped in the middle but distributed across the values that the students choose to use (sometimes notationally, due to place value and stem and leaf, although most did this only in form), can be missed in comparison to like values (modes). To me, the data showed the need for related but distinct explorations of mean, median and mode in the context of real discussions of typicality – not as definitions but as potentially different types of resistance to data changes. Again, I know Lehrer and Schauble are fully aware of these issues and have brought a number of them to light with their colleagues (Ben-Zvi & Garfield, 2004).

Besides the multiple meanings of middle, there is also an underlying idea of creating a number to stand for or represent a measurement, that is, to proceed from cases to aggregates, and then from aggregates to a statistic that stands as a measure of central tendency. In this sense, one can use a graph to display typicality, or one can use a graph to create a method to find, identify, or create typicality. Most of the students thought they were working on using a *graph* to display typicality, but one group chose to respond numerically. The group listed all the values for the heights of the plants on Day 19 in rows, and stacked identical values, but they wrote an answer for the question about typicality, in the bottom right corner, in the form of a single number, 160. This is an example of the beginnings of this transition from graphical display to a numerical summary (see Fig. 19.3).




```
Kristen: Well:: (1.6) they (0.2)
         kinda said it (0.3)
         ((a))here

Kristen: And then (0.6) also I
         guess I kind of (0.6)
         I look at it I assumed
         ((b))that it was that
         one ...

Kristen: they put the answer
         down ((c))here
```

Fig. 19.3 Kristen (on right) points out how one might see what was the typical Fast Plants height (Excerpt 9)

Spread, Prediction and Variability

This is a topic that some of my students (Meletiou, 2000; Confrey & Makar, 2005) have been exploring, and is linked to work such as that by Shaunassey, etc. In this work, we have, among others, indicated that attention to central tendency is often excessive in relation to expression and attention to variability.

With regard to this episode, I would agree with Clancey that spread is weakly motivated in the episodes observed, as these episodes focused on creating the displays. Perhaps the displays would have been different with a stronger setting of the question. Clancey wrote,

> After an hour into the third day, the teacher repeatedly asks questions such as, "Would this graph show you better—just the graph—how spread out it is?" [Excerpt 12, 1:00:42]. This entire discussion seemed boring to me. How can we talk about the quality of the graphs without talking about some issue involving plant growth? In the videos available to us, the described properties of the graphs are treated independently of the meaning of the numbers, which seems bizarre, given that the students actually came up with these numbers by measuring plants.
>
> The numbers were first bastardized when the two experiments were clumped on Day 26. The students appeared puzzled. Now they are just manipulating numbers. The idea of creating and comparing and presenting graphs is great, but then the inquiry has been moved from the plant domain—where graphs might provide value because the numbers *have value*—to the graph domain—a list of numbers and a generalized property called "spread out." In my viewing, the teacher gives the impression that "spread out" is of interest for its own sake, and that tools for talking about "spread out" (the graphs) can be evaluated independently of the domain from which the numbers come. (p. 269)

Clancey links this observation with a comment in the teacher notes about rockets, and ends by stating, "one might wonder [if] abstractions would transfer better if they were contextualized in the first place"(p. 270). Later, Clancey states what the primary point is to me, "Plants do get mentioned, but only with respect to 'what's typical,' not motivating the question about plant growth that might be answered by understanding variability" (p. 270).

Where I agree with Clancey's critique, not as simply an issue of contextualization, which is an overused and under-defined term, is in relation to what I interpret him to mean by "plant growth." Spread is not an issue of a graph's appearance; it's an issue of variability, and variability typically is viewed as the product of two sources, systematicity and chance. What seemed clear to me is that, again, two interacting or transactional elements are present. However, rather than seeing this as "boring," I think a more likely interpretation is that it is the teacher, more than the researchers, who is not fully comfortable with the idea of spread and hence limited to a view of it as shape more than variability of a real meaning, that of plant growth. My viewing of this suggested that spread is a new concept to this teacher, and that probably it was discussed between the first and second classes with the research team, and the tactic of suggesting 555 came from that discussion; that is creating a problematic by creating a large gap.

In my own design studies, I typically teach the classes myself, to provide me more freedom to explore the ideas with the students. When other researchers make the legitimate decision to work with another person as a teacher, then they have two levels of innovation and design to interpret and mediate, one for the students, and one for the teachers. Both must be attended to, and sometimes a teacher may seem instructionally heavy-handed, when s/he is actually enacting an idea, not yet fully self-realized, suggested by the team.

In addition, as a comment directed at the researchers, it appears to me that the idea of spread is assumed to be tied to the shape of the distribution, rather than to the variability of plant growth as expressed in the duality: typicality and variability. The challenge posed by 555 addresses the proximal case that students think of spread as meaning the range, and it provides the counter-example, as it were, to that. As range, they believe they have precisely and completely answered the question. The teacher is unsatisfied because he wants to think of spread as also involving how one treats or anticipates the challenge associated with gaps within the range. Hence he gives the example of 555, which both increases the range, but it reveals gaps. Listing the plants by number hides those gaps.

However, I believe that variability demands more of the teachers and students. The missing elements mathematically were probability and distribution. What is the likelihood of hitting your typical value in a prediction or a test? Spread is not simply the measurement of the points' distances away from typicality (variance, except its squared or absolute value is used). The question is perhaps, "how do you view that graph as an expression of likelihood?" This is a subtle concept that eventually leads to probability distributions, sample distributions and confidence intervals. In the videos, there are early precursors here which have not been commented on, yet were close to my favorite in terms of interaction.

For instance, in one small group, we enter as a member of the research team is discussing typicality in a way that relates fundamentally to spread. The students point out that 11 out of 63 values are in the 160 s. The researcher poses a question of what number of plants would be in that interval if they planted another 63 and Kendall responds:

Excerpt 7 [0:07:43–0:07:53]

```
0:07:43 Kendall:  Double that.
0:07:44 Edith:    Double this.
0:07:45 CH:       Double that?
0:07:45 Tyler:    ⌈WHY?
0:07:45 Edith:    ⌊(So its) about twenty two.
0:07:47 CH:       ⌈⌈You get twenty. Hmmm.
0:07:47 Tyler:    ⌊⌊WHY?
0:07:48 Edith:    Because in one batch of sixty-three plants you
                  get eleven so with two batches you will
                  probably get double that.
```

The students reason that the distribution would remain approximately the same, thus doubling the number of plants in the specified interval. Then the researcher poses the question "what would they expect in that same interval if they planted only 20 plants".

Excerpt 7 [0:08:20–0:09:01]

```
0:08:20 CH:       But if you planted less like twenty how many
                  do you think we would have around one ⌈sixty?
0:08:23 Edith:                                         ⌊Like
                  well if there were only twenty, I would say
                  like (.) maybe six or fa fou:r.
0:08:29 CH:       How would you how would you figure that out?
0:08:31 Kendall:  Well because ⌈uhh
0:08:31 Edith:                 ⌊Well from this side of it=
0:08:32 Tyler:    =Well we hafta do fractions first.=
0:08:35 Kendall:  =Eleven divided by
0:08:36 Tyler:    Eleven no thirty ⌈(.) sixty-three divided by
                  eleven.
0:08:39 Kendall:                   ⌊Eleven,
0:08:42 Kendall:  No:::, eleven divided by sixty-three.
0:08:46 CH:       And what would that=
0:08:47 Tyler:    =And then you time that by=
0:08:48 CH:       And what would that tell you eleven divided by
                  sixty-three.
0:08:50 Kendall:  Ummm
0:08:51 Edith:    It would tell=
0:08:53 Kendall:  =The percentage of the numbers that fall in
                  this category.
0:08:56 CH:       Okay.
0:08:58 CH:       Alright.
```

In order to answer the question "of 20 plants, how many would you predict would be in the interval of 160–169, the students recognize that they need to think about fractions." Tyler proposed a division problem, though at first he erroneously suggested dividing 63 by 11 (this is a common mistake; students often expect the smaller number to divide into the larger). With Kendall's help, Tyler corrects himself. Kendall is able to explain that calculating 11 divided by 63 will produce the percentage of the values that fall in that interval. By responding with the question and "what would that tell you, eleven divided by sixty-three, the researcher is drawing the students' attention away from the algorithm to how to describe outcomes as a proportion of data in any category, a precursor to the examination of a probability distribution." Furthermore, the researcher asks the students whether they can learn to see the dot drawing in terms of the proportion rather than the actual number, which is more sophisticated than reading off counts.

Excerpt 7 [0:09:01–0:09:49]

```
0:09:01 CH:       Does this graph show you that (.) pretty
                  pretty easily the percentage that falls into
                  each category?
0:09:06 Kendall:  Not really the percentage but like (3.1) the
                  amount
```

```
0:09:12 CH:        The amount that fall into each cate⌈gory.
0:09:14 Tyler:                                         ⌊It equals
                   seventeen point ⌈four six zero three one
                   per⌈cent.
0:09:16 Edith:                     ⌊What is that?
0:09:18 Kendall:      ⌊What did you do?
0:09:19 Edith:     What?
0:09:20 Jasmine:   He did(h) something.
0:09:21 Tyler:     I did the same thing as we do on ⌈morning
                   spelling on Friday.
0:09:22 Kendall:                                    ⌊What?
0:09:24 Kendall:   Eleven divided by fifty-three?
0:09:26 Tyler:     Yeah.
0:09:27 CH:        Mmmm.
0:09:27 Tyler:     >And then< times that by a hundred.
0:09:29 Kendall:   That's impossible!
0:09:31 Kendall:   Oh yeah maybe ⌈not.
0:09:30 Tyler:                   ⌊Yah.
0:09:34 CH:        So seventeen percent, ↑o-kay.
0:09:35 Tyler:     No, seventeen point five. You round up.=
0:09:39 Kendall:   =So that's really not that much but
0:09:41 CH:        Um hmm.
0:09:45 Tyler:     Well it's ⌈the biggest amount that we will get
                   for any of 'em so I would say
```

In this final exchange, Tyler takes the lead, first in obtaining the calculator to carry out the calculation, and then in explaining the 17.5%. He recognizes that the interval 160–169 is the largest group, counting Kendall's assertion that "its really not that much," and arguing that it holds instead the highest percentage of data.

These questions are very clever and insightful. They begin to move towards probability, distribution, and expectation. They bring the students to discuss the meaning of percentages quite competently. While this does not answer Clancey's challenge, as another designer, I could see how this discussion would be subsequently coupled with the discussion of growth over time to produce a rich understanding of variability in relation to growth.

In the end, however, to my eyes Clancey missed the key curricular goal, which was the understanding of variability, not the issue of graphs. The beauty in the work of Lehrer and Schauble is that by linking science and mathematics with statistical reasoning, they are teaching the children about modeling. Modeling, for Lehrer and Schauble (2004, 2005) starts with iconic representations, inscriptions, metaphors and builds towards models. This is truly inquiry in a Deweyian way, which Alan Maloney and I have revised in order to apply those ideas more directly to modeling, which we have defined as

> ... the process of encountering an indeterminate situation, problematizing it, and bringing inquiry, reasoning, and mathematical structures to bear to transform the situation. The modeling produces an outcome—a model—which is a description or a representation of the situation, drawn from the mathematical disciplines, in relation to the person's experience, which itself has changed through the modeling process. (Confrey & Maloney, 2007, p. 60)

In the part we watched, we saw how one particular area is emphasized, to make a coherent piece for our review, but to describe it as myopic is to mistake the local for the general. In their general scheme, mathematics and statistics are the tools for more and more effective viewing of various scientific ideas, and as tools, there are times to learn what tools are by using the tools, and there are times for extending the tools themselves through observing and concentrating on them.

Disciplines, Theories and Models

Now, however, I return to the issues of disciplines, theories and models. Clancey's discussion of transactionism is complex, so complex that one wonders if one can look through it to see episodes such as these. To my mind, for a theory to act as a lens on events such as teaching and learning, it must simplify it. The lens must focus one's attention and must clarify and explain. Clancey's theory seems to me to be broader, more like that of a paradigm, more than a theory; perhaps in the category that diSessa and Cobb (2004) refer to as "grand theories." For usefulness and parsimony, a model should not exceed the event it models in complexity. Otherwise the map can be confused for the territory. In a science of practice of teaching and learning, where practice is inherently complex, the individual lenses have to be relatively simple, but overlaid to rebuild interpretable complexity – a point made by Sharon Derry as a result of her work with teachers. As a grand theory, I have no problem with transactional theory; my own theoretical commitments lie within pragmatism, second cybernetics, and constructivism.

So, in order for me to make use of transactional perspective, I would need a set of smaller, more focused theories that could be projected onto the events to help me to pass through them. Such theories would be designed to provide instructional guidance to teachers, while respecting the impossibility and undesirability of attempts for complete specification of upcoming events. This thinking led me to consider the question of what the role of a discipline is within a transactional framework. That is, what is mathematics? Foremost of all, this is a mathematics lesson. That is to say, the primary goal is to teach mathematics, or in this case, statistics. It seems to me that in creating a means to interpret the practice of teaching and learning mathematics, mathematics must play a critical role. Too often in studies of student interactions, people push the mathematics to the background, only an occasion for studying human learning, or adult child interactions.

Now, while the statement can be interpreted as essentially conservative or traditional, it is perhaps not. For I believe, like Jim Greeno, that the welding of cognitive science with interactions has the potential to transform what we mean by a discipline, but only if it is done with sufficient consideration of received knowledge. The challenge is to find the proper balance, so that emergent behavior is recognized, valued, and supported, at the same time as authorized knowledge is also challenged, examined and re-defined. It is in this space that I encounter a dilemma, similar to Plato's paradox of learning in the *Meno*, in which Socrates muses over how one can ever learn without already knowing what is to be learned. Likewise, disciplinary knowledge must guide a transactional perspective without leading it by the nose and thus determining its course in ways that unduly constrain creativity, originality, and syntheses.

How to do this methodologically is interesting. In my own work, I have developed a heuristic I refer to as voice and perspective, where the research teams I lead tend to discuss students' voices as we hear them through our expert perspectives, but then reverse and discuss the necessary changes to our perspective that occur as a result of listening to students' voices. In light of Clancey's paper, this dialectic can be viewed as deeply transactional. In light of this meeting, I can also see that we need a much more diverse set of frameworks for considering voice, in terms of affect, humor, authority, participation, and so on. Through the specificity of creating a program of studies of the practice of teaching and learning mathematics/statistics, perhaps we can remake the idea of disciplines, and in order to be warranted in that process, the discipline must play a significant and yet flexible role.

A solution to how to use the structure of a discipline in a pragmatic fashion paying it close attention as a resource for interpreting these interactions lies in the concept of a model. If transactionalism is a form of "grand theory," then we further need domain-specific theories of how to learn particular concepts or ideas. If one views mathematics as a model for making sense of experience and the world, then analyzing praxis is a form of modeling, through the analysis of transactions, how students are coming to use mathematics as an effective model of experience and the world. If one uses the Deweyan notion of inquiry as the basis for modeling, that is, the transformation of the indeterminate situation into a determinate situation, then what I am claiming is not that the disciplinary perspective be imposed on the interaction a priori, but that it be used as a tool in modeling the interaction, as opportunities to do so present themselves. In an educative situation, the goals and intentions of the teacher, or the lesson, can provide a worthwhile starting place. In light of this set of papers and discussions, I would suggest that a potentially productive collaboration could be developed around the interpretation of real classroom episodes or praxis. In such an exchange, one would want to strive to ensure that transactional perspectives, generated primarily from the apparent joints of human interactions and respecting the playfulness of emergence would be compared and contrasted with the observations of mathematics and science educators, dedicated to seeking out and documenting these conceptual corridors, linking to pathways to deep and proven science and mathematics ideas. It would be at the interface of these two perspectives that I would expect to find interesting and compelling means to improve instruction.

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Chapter 20
A Transactional Perspective on the Workshop: Looking Again and Wondering

William J. Clancey

Introduction

My target chapter begins by stating the charge I was given by Tim Koschmann, to "relate the 'transactional perspective' to a practice-based science of teaching and learning," which I understood as referring to the work of John Dewey and situated cognition (Clancey, 1997). As Säljö eloquently explains (pp. 281–282), my chapter has two faces, with different scientific intentions: the first to inform cognitive science (particularly theories of memory, conceptualization, and consciousness), the second to inform instructional practice. In this response to the commentaries I will revisit these two objectives and discuss others' remarks that have stirred me and might be useful for future work to consider.

I was so buoyed by the commentaries' constructive and helpful tone, I proceeded to read all of the other chapters. I find them wonderfully articulate, with delightful and inspiring nuances about theorizing, theories, teaching, and learning. Several of the articles caught me short, particularly Confrey's commentary on my chapter, which I will focus on here, and Macbeth's commentary on Greeno's analysis, which I will simply recommend for careful attention.

In interpreting my chapter it is helpful to recall the intellectual demons that haunted me in the 1990s. Like Greeno, I have a background in cognitivism, which is perhaps always "the last war" that I am continually fighting (like Vera and Simon's [1993] anti-behaviorist response to situated cognition). This battle is partly always in my own mind, as an unending fascination over theories I once believed about human memory, knowledge, and reasoning. The battle is also an argument with friends and colleagues in my original artificial intelligence community of practice—people who are not just fighting the last war, but are still in the trenches, believing they might win (e.g., Nilsson, 2009). After two decades I no longer enjoy pursuing this missionary discourse. I now believe that paradigm shifts occur by forming new

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scientific communities, not by transforming belief systems of academics, even when they are our friends. Cognitive theories of learning have largely failed to account for discourse across entrenched points of view, where denial is the easiest way to deal with discrepant information (Clancey, 2005).

I remain fascinated by the transactional perspective because it seems fundamental for addressing common personal questions about meaning, reality, and purpose. In particular, the commentaries have caused me to wonder what we accomplish in classes that teach math (e.g., geometry theorem proving) as a *tool* independent of a practical inquiry, and on a broader the scale, the relevance of a practice-based science for teachers and learners.

I begin with the issue of cognitive science, then consider Confrey's commentary, and finally revisit what a "practice-based science for teaching and learning" means.

Informing Cognitive Science: Neuropsychology and Humor

As Säljö notes (which I restate here in my terms), as a cognitive scientist I believe a transactional view might enable us to see and articulate the multithreaded nature of change occurring in the classroom, including aspects of disciplinary curricula, personality, economic utility, and so on."Transactional" is understood here as being about change, the dynamics of development, expressing and reflecting on interests, concepts, and emotions within a dance of mutual influence. Thus I interpret a transactional perspective as a broad orientation for analyzing systems; in particular, how to think about causality (see Macbeth's remarks about situated action and Clancey [2008]). I asked "how inquiry might have occurred differently in the classroom we are studying." A transactional analysis provides insight by revealing what is particular about these happenings. "How it could have been different" shows influences, choices, and intentions in the unfolding dynamics.

Throughout, I viewed myself as interpreting Dewey's theory, not "Clancey's transactional perspective" (pace Chapter 17, Chapter 19). In this respect, the analysis is philosophical: seizing on some phrases and distinctions, making them my own, and then using them to point to, articulate, and explain what interests me.

In elaborating the notion of "inquiry," I seized Dewey's biological metaphors and grounding to ask what contact I could make with neuropsychological aspects of cognition—as I then understood it (presented broadly in Clancey [1997] and as a neuropsychological theory of conceptualization in [1999]). I illustrated Dewey's notion of "transactional inquiry" by putting on those eyeglasses and examining the videos for events in which perception and humor were salient. Thus, I was delving into two ends of the "neural-psychological-social" spectrum not related well by cognitivism: the non-verbal aspects of conceptualization (visible in how the class talked about marks on the graph paper) and the social aspects of conceptualization (visible in both small and large group bantering).

With respect to humor, I wrote, "This perspective makes salient functional aspects of behavior that were generally ignored by 1980s cognitive science studies of problem solving and instruction, in particular, the role of emotion in conceptual change" (p. 276). I stress again that my research interest is to make dreaming, humor, consciousness, autism, and so on an integral part of cognitive science. I have argued (Clancey, 1999) that this means making contact between accepted cognitivist theories (e.g., hierarchical models of language processing) and neuropsychology—by which I mean explaining how well-established psychological processes of remembering, speaking, and reasoning occur in the brain. Rather than viewing neural processes as matters of "implementation," I have argued that the architecture of cognition, including especially how categories in different modalities (touch, hearing, vision) are formed, organized, and coordinated over time must be understood if we are to explain the full range of human mental experience and behavioral capability. The cornerstone claim is that theories of conceptualization are woefully insufficient, particularly in accounting for varieties of consciousness. In particular, the dominant "cognitivist" theories of the 1960s–1980s, based on the notion of semantic (concept) networks, are gross simplifications based on a fundamentally wrong metaphor of human memory as storage—that "knowledge" is something static that can be put away and taken out like tools from a shed. Elman (2005) presents the kind of process theory of memory that I have advocated.

In short, I saw the workshop, the tapes, and my charge in the target article as an opportunity to expose human behavior that cognitive science needed to incorporate, here specifically, in a science of teaching and learning.

Säljö is correct that my analysis of the classroom humor is not "grounded in neuropsychological concepts or assumptions" (p. 285). My intent goes the other way: Speaking to cognitive scientists and AI researchers, I am saying, "Look, humor is not epiphenomenal, it is a naturally occurring, universal part of human experience, and our nascent theories of situated action imply that humorous behavior reveals aspects of the neural structure and processes of conceptualization." So by my perhaps idiosyncratic reckoning, to talk of humor is to talk of neuropsychology. Or put another way, humor has not been admitted as being part of "cognition" proper, and a science of teaching and learning practices offers an opportunity to elevate its importance.

Again picking up on Säljö's comments, my hope is for "the promises of modern biology" to relate theories of memory and learning to how the brain actually works and to reveal how our brains are as different as our bodies,[1] as opposed to being like identical INTEL® processors. I want cognitive science to explain why some of us can draw and play music by ear, and others excel at math puzzles or gymnastics, etc. For example, I couldn't play the piano even half well until I learned folk dancing—rhythmic action that coordinates feeling, seeing, and moving. What aspects of attention and sequencing are at work here? Understanding the neural aspects of rhythm and musicality is part of the study of multiple "intelligences" (Gardner, 1985). A more inclusive cognitive science—partly created by theorizing learning practices—will provide a better basis for using theories of cognition to inform pedagogy. I have assigned this exploratory exposition to the discipline of "neuropsychology," with the strong heuristic that it is the full range of cognition—including dance, dreaming, drawing, and dysfunctions—that will reveal how ordinary reading, writing, and arithmetic are possible for human beings. What indeed are the "basic skills" of cognition? How do minds develop to account for proclivities and talents? What might we teach to bring human experience together in more holistic, fruitful ways?

In summary, my analysis of humor in the classroom video has multiple aspects: 1) calling out humor as being an aspect of classroom practice, 2) characterizing humor as involving physical processes of conceptualization in the brain we have barely begun to unravel, 3) using the analysis to argue that cognitive science should not be ignoring humor, but should accept its dual functional nature in the development of a conceptual system (in the brain) and a social system (in human relations).

This part of my target chapter illustrates how a practice-based science of teaching learning need not say anything directly about instructional design—that's the province of a *science-based practice* of teaching and learning. As Cobb (pp. 291–293) allows, one measure of scientific progress is insight, an enriching of observation, seeing ordering and meaningfulness in behaviors that might otherwise be glossed over as irrelevant or aberrant. In this respect, I am content with my foray into the discussion of humor.

My discussion of graphing comes from another direction, using theories of learning for guiding instructional design.

Informing Instructional Practice: What Is the Point of the Graphing?

Confrey's commentary provides for me the heretofore secret key to the classroom videos—the lesson plan from a mathematics education ("disciplinary") perspective. She says, in what feels deeply ironic to me, "In an educative situation, the goals and intentions of the teacher, or the lesson, can provide a worthwhile starting place" (p. 335). On reading this remark, I was befuddled: What was the workshop about if we did not start with the teacher's perspective or know Lehrer and Schauble's experimental plan? How could I have analyzed the videos without knowing that the "key curricular goal (was) the understanding of variability, not the issue of graphs" (p. 333)? Further, in my grasping for context, I thought that when the teacher referred to growth rate ("fast plant")—he meant plants that were growing faster! I didn't know that these are Wisconsin Fast Plants®. Did the students and teacher share an understanding of "spread" as well; and I, not knowing this background, saw these repeated mentions as ungrounded and forced?

In their introduction to the classroom (Chapter 2), Lehrer and Schauble (L&S) describe their research program as investigating "modeling approaches to science" (p. 21). They view their presentation in this book as essential background "before readers dive into the chapters" (p. 20). Why wasn't this provided as background reading before the target chapter authors viewed the classroom videos? Hall's commentary shows that he was conversant in L&S's research program; had I failed to do my homework? I checked my notes and files, and found this note to Koschmann from August 15, 2003:

> I need a thorough understanding of Rich Lehrer's work. Can he send us a paper that presents his study, interests, and findings over the past two years? I don't think we should work in a vacuum. Given that an informed observer has worked on this for so long, let us reflect on his perspectives rather than try to work out of context from scratch.

Lehrer is copied again on September 9 with a request to post the papers, but we didn't receive a list of L&S's publications until an email on December 12, with the papers arriving December 19, a month after the November 2003 workshop. A year later, Koschmann reports in an email that he has "discovered a piece . . . describing the classroom study that we discussed in the workshop," namely (Lehrer and Schauble, 2004).

I completed my target paper first draft in October 2003. Fully occupied by the amount of data and my task, I assumed that the world of the classroom was what was visible on the tapes. Then in responding to comments on my target paper, with the primary focus on shortening it, I never read L&S's papers until now. Confrey's commentary was the first attempt to directly communicate to me the educational research design of the class sequence.

Based on the videos I saw and limited background, I complained that the students and teacher "are myopically talking about the graphs as objects in their own right, removed from a plant-growing activity." But unknown to me, in other classes the "students discussed changes in the distributions of measures and interpreted what the 'shapes of the data tell us' about changes in the plants" (Lehrer and Schauble, 2004, p. 7). Further, the students grew the plants to answer, "questions about the effects of light and fertilizer on growth" (p. 334). So the overall activity was not just about growing plants to generate height data for the sake of teaching statistics concepts.

In the classes for which we have videos, Confrey explains that "the primary goal is to teach mathematics, or in this case, statistics" (p. 354). Hall says the purpose is "inventing statistical displays" (p. 360). He cites Lehrer and Schauble (2004) that the students are led to "invent their own representational conventions and then to evaluate the resulting displays against their evolving criteria for communicability and mathematical precision" (p. 669). Confrey (p. 386) says something similar in emphasizing the activity as a time to learn what the tools are (e.g., generating histograms), rather than applying them.

Wertsch explains how the lesson conveys cultural conventions for creating statistics graphs. The pedagogical theory is that these mathematical ideas should be "put in place" before they are "needed to support the modeling approaches to science" (Chapter 2, p. 21). Thus, the initial graphing activity had a scientific motivation, but it is not mentioned in these classes. The topic was not (only) "variability" in a pure statistical sense, but "natural variability," specifically variability in mathematical descriptions of causal processes in a population. Thinking in terms of a population (versus individual entities) is an important concept in the 28-day lesson plan. The graphing activity aims to teach about detecting or visualizing natural variability, when they are viewed in the later classes as scientific models. Not knowing the designed curriculum sequence, I was disconcerted by the absence of a guiding purpose for organizing the data—a context for evaluating the adequacy of a particular visualization of “spread” or “typical” in providing *information*.

Did the other workshop participants know the overarching curriculum? In the twenty target and commentary chapters of this book only L&S themselves refer explicitly to “natural variability.” However, Sherin stresses that the instruction is about the “natural world” (p. 195), and Collins notes, “By plotting variability of plant growth in a bar graph, they could see how a normal function arises naturally” (p. 107). Many authors do mention “variability,” which Hall highlights as important knowledge of the classroom history: “So in looking back, we find prior cycles of collecting and displaying data with variability.” But again, aside from the reference to scientific modeling by L&S, Sherin, and Collins, everyone views “variability” in a set of numbers having a “distribution” and “central tendency” as being what Derry, for example, calls “statistical ideas,” in contrast with “science ideas such as force and friction” (p. 228).

In sum, 14 chapters out of 20 do not relate the observed graphing activity to L&S’s scientific modeling lesson plan (excluding Koschmann’s introduction and the other responses to commentaries, which are not available as I write). Several observers make observations similar to mine; for example, Greeno says, “In the case of spread, there was no reference to the plants. . .and the discussion seemed entirely focused on the variability of numbers” (p. 60).[2] So two groups—the students and the workshop participants—were dealing with the graphs as displays of statistics concepts, as tools for talking about numbers, without addressing their value for “communicability and precision” in a scientific model. Does this matter?

Would the classroom sessions we observed have proceeded with more alacrity, engagement, or scientific depth if the scientific context motivating what and why you need to “see better” had been restated throughout? Would the term “spread” be more meaningful if coupled with mention of populations and natural variations? Examining again the teacher’s framing of the graphing activity on the first day [Excerpt 1, 0:00:07–0:05:34], we see references to “how spread out” and “the range” and no mention of “population” or “natural variability.” By design, the scientific modeling context was omitted from these initial steps toward thinking about distribution (see Chapter 2).

In contrast, one could continuously refer back to what the graph, as a model, is telling us, how it in-forms the situation, structuring and orienting our grasp and action within some project: Show how a problematic situation might be resolved with statistical concepts. For example, start by graphing a population of plants grown under different lighting conditions, where variability might be correlated to the amount of light. Then ask what variability might be normal in plants grown under the same conditions, thus motivating the graphing in the classes we observed. The distinction between accuracy and precision could then be tangible (Alder, 2007).

Besides feeling sorry for the students, as a workshop participant I regret that I did not know L&S’s intentions or the background of the class. We might have had a different kind of workshop, one that started with L&S’s project, framing the classroom activitywith respect to their goals and the curriculum. Following a typical approach in video interaction analysis (Jordan and Henderson, 1995), we might have viewed the videos with Confrey, Lehrer, Schauble, and Rolfing during the workshop, hearing their interpretations and inquiring about their intentions and experiences. An evaluative workshop, oriented around the design of the class, would have put our intellectual tools to work—not just to use the videos to illustrate theoretical points, but to apply these theories for guiding instructional design.

But speaking apparently to the contrary view, Cobb remarks (p. 300) that it was important for our project to have an inquiring, not an evaluative perspective. We came in cold (most of us) and knowing the overall genre of the setting, were asked to study multiple sessions and small group activities, and to bring to bear our ways of looking, talking, organizing materials into a scientific presentation. In that exercise, Greeno, Wertsch, and myself selected materials that allowed us to develop the themes that interest us (Fred Erickson summarizes these selections in Chapter 20). The commentators then refined our presentations along multiple disciplinary dimensions (e.g., Garrison's (Chapter 16) very fine amplifications and elaborations about Dewey; Cobb's (Chapter 15) mention of symbolic interactionism; Säljö's discussion of cultural institutions).

Recently Koschmann asked me, "Does knowing the mathematical intent of the class and the series of prior classes change your analysis?" No, but now the point about using graphs to provide information shifts from being a kind of tutorial ("here is what a modeling analysis looks like") to an expression of how strange it seems that three hours or more of classroom time would be about graphs without explicitly relating them to the broader inquiry about populations or plant growth. Pedagogically, the activity was aimed at first teaching tools for such an inquiry, but what is the meaning of a tool outside the context in which it appears? Statistics, like logic and geometry theorem proving, can be a kind of language game; an inquiry might just be about numbers and the shapes of distributions.

Why not begin with the practical questions? By a transactional perspective the subject matters of plant growing experiments, biology population theory, and statistics are mutually influencing—in scientific practice, in social-historical development, and in individual understanding. An either/or, linear notion of first learning the tool and then learning the application is antithetical to a transactional perspective, in which the understanding of "what the tools are" (theory) is conceptually coupled[3] to what you can do with them (practice).

The traditional curriculum ordering of mathematics, science, and engineering views these disciplines as cumulative, assembled in the mind like subatomic particles, elements, and molecules of thought. Dewey's approach was to begin with "community life" and in particular occupational activity, just as a "model farm" that would motivate the conventional school topics (Dewey, 1896; Westbrook, 1993). The graphing activity fits Dewey's philosophy in inventive form, but not purposeful project content—learning statistics has been separated out from the problem it will resolve, which will only be presented later when the students are "ready" to tackle it. If this context (e.g., farming) were the ongoing topic, the more general scientific modeling ideas and experiment analysis would then be pervasive in the discourse, and could guide and better motivate the graphing activity than mathematical qualities of the numbers alone. Imagine for example framing this entire discussion within the current debate about global warming, where natural variability plays a key role. The plant growing experiments might then be introduced as a way to help the students evaluate political and economic issues facing their community.

What Is a "Practice-Based Science of Teaching and Learning"?

In the final section of my target chapter I explored the task of developing a science of instructional design. Confrey also frames her commentary in terms of the usefulness of the transactional perspective for mathematics instruction. But the title of the workshop proposal, "Coupling Theories of Learning and Research on Practice," and Koschmann's introductory chapter, "Theorizing Practice," do not necessarily promise practical results for instructional design. Our social-psychological theories (situated action, dialogic theory, and transactional inquiry) might help us model classroom practices, describing and/or explaining what occurs, without also being used as tools for formulating classroom activities.

Erickson indicates that our charge has been to "critically evaluate the theories in terms of what they made (and failed to make) visible in the videos" (p. 395). Similarly, Koschmann's original proposal said that the purpose was to determine what different theoretical perspectives could elucidate about "actual classroom practices" or more specifically, what produced learning outcomes. Going beyond this, relating learning outcomes to pedagogy and thus providing constructive assistance to L&S's research project, would have required a different analysis, for example, considering the separation and ordering of the statistics and scientific modeling discussions by examining a variety of classes in the 28 day sequence.

Reflecting on the course of our writing, we see how our own analysis has a transactional quality that both interprets the past and prompts new interpretations. I wrote, "Actions are *commentaries* that promote reconceptualizing . . . what has transpired (i.e., what are the events of the past) and what the past means going forward" (p. 276). And so the transactional perspective is a way of understanding these investigations, including our examination of the materials (both the videos and our chapters), and the workshop overall.

For individual researchers and the community, developing an understanding is a back and forth, reflective process (Schön, 1987): I interpret my own chapter and reflect on what it accomplishes, trying to understand better and articulate my "original intent"—and struggling to prove to myself that my ignorance of L&S's research program doesn't invalidate my remarks. The variability in the population of chapters provides further evidence for evaluating the classroom videos—and the Allerton meeting in 2003. We look again at the transcripts; reflections on our analysis prompt reorganizing the data (and even our chapters become data). I look again at the workshop schedule, wondering, what did Lehrer and Schauble say after my presentation on Sunday morning, November 23, 2003? Our writing sparks new conversations: Garrison and I exchanged a handful of lengthy emails (in which I sought to better understand Dewey's "acausality"); Confrey and I spoke on the phone for over an hour, as I learned for the first time a teacher's perspective on this whole enterprise. Then I "went back" to watch the video of Confrey's workshop presentation, comparing her remarks to her subsequent paper; and seeing myself in the first row wonder why my understanding today seems so different. Perhaps we are ready for another meeting.

Notes

1. "Brains differ from person to person, just like hair colour, height, the pattern of the facial bones and the proteins in the blood" (Norman Geschwind quoted in Miller [1984, p. 129]).
2. Greeno, Lehrer, & Schauble (2004) provide an interesting re-contextualization in discussing the variability of the population of *representations* and the students' selection among them.
3. As a clarification for Säljö's concern, I use "coupling" (Clancey, 1997, 1999) to refer to a causal process of co-determination within a neural or social system, not a relation across systems of analysis, such as between biology and sociology.

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Part V
Synthesis

Chapter 21
Do Moments Sum to Years? Explanations in Time

Richard Lehrer and Leona Schauble

When Tim initially contacted us to discuss the workshop that culminated in this book, what persuaded us to participate was the potential to learn more with colleagues about the relationships that potentially hold among events in shorter-term and longer-term time frames. How does what happens over a relatively brief period – interaction patterns discernible in the moment, a lesson, or across months – contribute to the forms of reasoning, disciplinary knowledge, and identity that a student develops over the years of his or her educational history? We have been mulling over this issue for a number of years (Lehrer & Schauble, 1994) because our work in K-6 classrooms forces us to consider how explanations of relatively local events connect with explanations of longer-term development.

Based on the longitudinal research that we conducted in Wisconsin, where we had the opportunity to follow students for up to half a dozen years of schooling, we suspect that the relationship is not a simple or additive one, and some of the chapter authors make precisely that point. We are intrigued by the implications of conceiving of development as embedded learning histories, but we suspect that we do not understand much about how those histories coalesce to form an overarching story. How do episodes at a local level of time – which have their own structure and form – contribute to longer-term accounts? For example, it seems intuitive to expect that particularly consequential outcomes must be the result of unusual causes, but this is not necessarily the case. Perhaps, instead, a consequential outcome is most likely to result from an accumulation of local events that are gradually integrated over time to produce a profound shift in, say, a person's epistemology or a system's capacity to support particular forms of practice. The relationship between encompassing

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and constituent time frames is not necessarily a self-similar one. A good example is Clancey's (Chapter 15) analysis of the ways that humor may appear as an emotional expression in the face of conflicting ideas and also jog participants beyond their apparent cognitive logjams.

Although all who participated in the workshop tackled these questions with verve, we agree with Erickson (Chapter 23) that the progress we made as a group is probably best described as a modest first step. Perhaps that should not be so surprising. Our field has spent relatively little time on this issue, and it is only recently that we have had the tools and the commitment to begin to take it seriously. Because academic research favors specialization, most people tend to stick with analytic frames and methods (and consequently, the interpretive lenses) that constrain their viewpoint to a particular time scale and a favored way of looking. What we learned from the workshop (and from subsequent reflections, such as Erickson's history of interaction research) is that negotiating these differences is a very difficult task to undertake. Some participants (Rich and Leona) had intimate knowledge of the context and players, as well as some notion of how things came out for these students over their 6 years or so in the school where the research was conducted. Other workshop participants possessed both the advantages and disadvantages of a more limited, but also more focused and disinterested view of these children. Most of the chapter authors tended to zoom in on small slices of behavior and conduct extensive analyses at that level. This focus provided a different viewpoint than the one we typically take, because we tend to be both forging and questioning educational goals that cross several years of instruction. What we found particularly promising about the enterprise proposed by Tim was the potential that these focused analyses might generate some conjectures about what was likely to unfold over the long term or how that unfolding might take place. In all cases the conjectures were plausible and thoughtful, although it is probably inevitable that some rang truer to us than others.

One central challenge that this kind of collaboration raises is around selection and representativeness. We selected a corpus of material for analysis, and this selection was guided by a number of considerations. For example, Tim cautioned that the mathematical and scientific content needed to be obvious enough so that researchers not immersed every day in those disciplines could easily see what we were trying to accomplish (as we will explain, we are not sure we succeeded in that goal). Because no one has time to review hundreds of hours of someone else's data, the videotapes what we provided overed 28 days in one of the 44 classrooms (grades K-6) where we worked over a dozen-year period. Moreover, these recordings were not made for the purposes of supporting analyses of the kind that many of the workshop participants regularly undertake, so, as Erickson points out, they have shortcomings for this purpose. The 3 days analyzed by conference participants represented the initial days of the unit. From these episodes, each analyst made a further selection of material for more extended investigation and commentary. As Tim suggested in his instructions, people identified patterns or episodes of interaction that they considered interesting or exemplary of important issues in teaching and learning. They had, however, no way of knowing how frequent, characteristic, or eventually consequential to the participants those episodes were.

As a result, there are occasional instances where we felt that our colleagues may have failed to grasp our educational intent, or alternatively, may have made predictions about outcomes for a particular child that we know did not, in fact, occur. This is not astonishing, given that the workshop participants received the videotapes without background or introduction. As Clancey suggested, the decision to proceed this way probably made some misunderstandings inevitable, and the results might have been different if all of us had had the luxury of more sustained discussions. For example, although many of the commentators apparently believed that the instruction was about ways of graphing data, we were only secondarily preoccupied with graphs or graphing, The immediate history of the participating students already included rather extensive experience with graphing, including the construction of coordinate graphs to depict rates of change. For example, Fig. 21.1 depicts a display developed in the classroom during the week preceding the episodes selected by analysts. It was constructed to compare different rates of water transport by wicks with

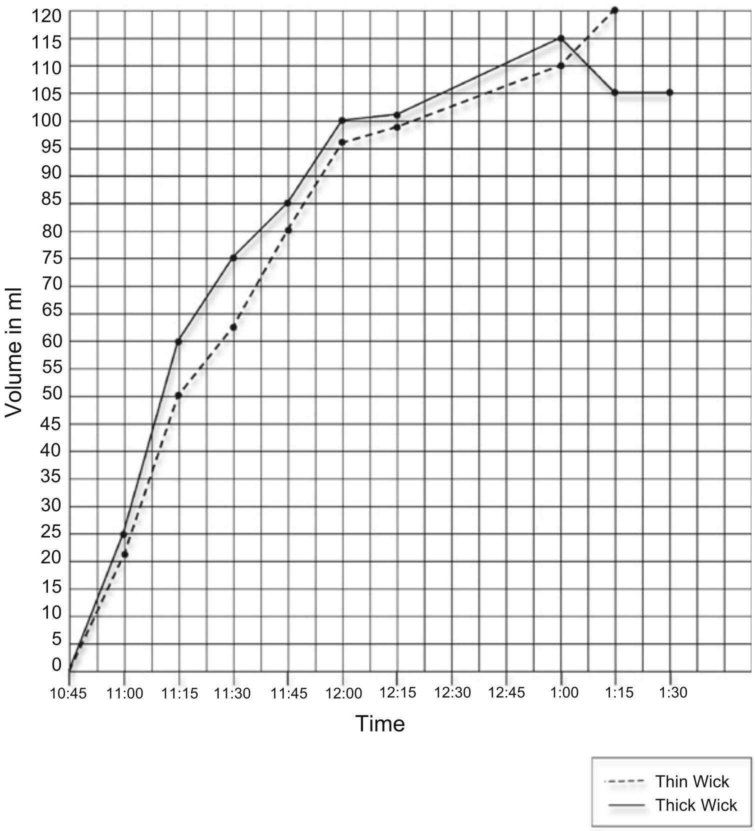

Fig. 21.1 Comparing rates of water transport with volume-time graph (facsimile copy of students' graph)

varying diameters (wicks are used to conduct water in the apparatus that supports the growth of the Wisconsin Fast Plants®).

Given the focus in earlier grades on individual, organismic growth, which had been supported by attribute-time graphs like the one in Fig. 21.1, our primary educational intent was to support a shift toward thinking about variability at the population level, as Confrey (Chapter 19) noticed. Students were clearly aware of plant variability in the sense of individual difference. That is, they knew that some plants were taller, some had more flowers, and some were wider (i.e., larger canopies). The purpose for asking students to produce and evaluate different forms of data displays was to surface and discuss issues about whether and how the different displays made it possible to easily "see" typicality and spread in the population ("see" in the sense explained by Goodwin, 1994, where a display technology renders phenomena visible in ways that are otherwise not accessible). We should also mention that we agree with the chapter authors who felt that we were overly heavy-handed at times in moving this agenda forward. We have learned a lot about how to handle these issues more productively in subsequent replications, and our current approach, most recently implemented in Nashville and Arkansas, moves more incrementally from issues of data display to inventing measures of center and variability and then reconsiders the generation of the shape of the data and statistics by constructing models of chance (Lehrer, Kim, & Schauble, 2007). Focusing on these ideas sequentially rather than simultaneously gives students greater opportunity to engage in evaluation of what different displays "show" and "hide," in the spirit articulated by Greeno (Chapter 3), thus supporting development of representational and meta-representational competence (Chapter 5 by Collins) and of measures of variability that tend to coordinate center and spread (Lehrer & Kim, 2009). We trust, as Derry and McClain point out, that readers understand that initial iterations of a design study are inevitably going to show rough spots. But, as Macbeth (Chapter 4) suggests, no matter the number of iterations, introducing an innovation involves conversational and material transactions in which the implications of some forms of activity may only subsequently be considered as disciplined by participants. We read the studies of workplace practices by our colleague, Rogers Hall, in this light, especially the development of "disciplined perception" (Stevens & Hall, 1998). When we first began working with MR, the participating teacher, he had the habit of sanctioning personal allegiances in the classroom by inviting students to ballot to resolve mathematical disputes, and we aimed to re-direct the grounds of argument as respectfully but firmly as we could (The teacher suggested balloting to demonstrate his concern with student viewpoints, and he was unaware that this practice distorted the grounds for mathematical argument.) As students were inventing displays to show qualities of the collection of Fast Plants, we also wondered if some might be projecting the 2-dimensional Cartesian system established earlier to characterize rate-dependent phenomena to describe the population of plants at a point in time. Did they take the task to be construction of the form they were most familiar with – the line graph? If so, how did the group trace the implications of the collapse of dimension (time)? How would their proposed system work? That motivated some of our questions, which we intended not in the spirit of, "Guess what I am thinking," but rather, "How does your proposal address the question?"

Some of the chapter authors raised objections to our approach to statistical reasoning, but we remain unsure whether those disagreements are genuine or are primarily due to what colleagues were able to see in this limited slice of the data. For example, Cobb (Chapter 17), Greeno, and others concluded that students were being asked to think about a set of bare numbers, stripped of context and meaning, and were therefore not actually reasoning about plants at all. They make the case (one for which we have considerable sympathy) that genuinely statistical thinking is always grounded in what one is reasoning *about*, including what one knows, what one wishes to know, and the potential stakes for drawing the wrong conclusion. We believe the impression that students were simply fiddling with meaningless sets of numbers (while the plants "disappeared") may have been lent by the fact that authors viewed only a restricted set of the episodes, although it may well reflect a genuine difference in point of view about the development of statistical thinking. As is evident in the complete corpus of video, the plants were always at hand and were continually the focus of class discussion about appropriate care, measurement, and change over time. We take the lack of their explicit mention in some of the turns included here as a signal of their ubiquity, not their absence.

A few authors also suggest that some of the students might have experienced a loss of agency during their interactions with us or with their teacher. From our perspective, we were attempting to hold students accountable to the goals of the display; we were conscious of an unfortunate history in the classroom to resolve mathematical contest by vote, rather than by particulars of argument. In any case, there are multiple instances throughout the 28 days of instruction of fruitful contributions subsequently made by the students identified as potentially silenced. For example, the group in Excerpt 5, described by some chapter authors as having their ideas over-ridden by adults, went ahead and produced a plot consistent with their emphasis on individual plants. This outcome suggests that they suffered no long-lasting loss of collective agency. Similarly, one chapter author felt that RL's agreement in this clip with one of the students who wanted to produce a "stem-and-leaf" display (see Fig. 21.2) instead of a case-value plot suggested that he was being too quick to promote the use of statistical conventions. In fact, RL encouraged this student to go ahead and produce the "stem-and-leaf" because this convention was *not* familiar to the class, and RL was hoping to see what he thought a "stem-and-leaf" might be.

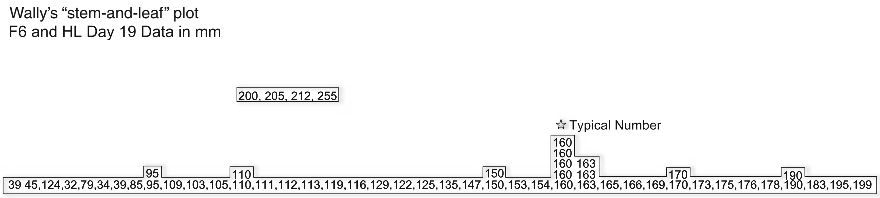

Fig. 21.2 Student's notion of a "stem-and-leaf" display

It turned out that this was simply a term introduced by the student's older brother (an eighth grader) and casually overheard. As a result, the graph the student produced was not conventional, although it did reflect his conviction that some groups of plants should be represented, even as he preserved their individual quality (the student's actual graph can be seen in Fig. 2.2). At another point, RL is talking with a student who is referring not to the plants of this investigation but rather to a context of measures of the apogee of a rocket the previous year. We make these points to underline our major message in this conversation, namely, the dangers of assuming that moments are fractal and that histories can be regarded as simple accumulations of these moments.

Returning now to the broader issue of what it means to reason about populations, we believe that a benchmark of beginning to think statistically is to be able to coordinate what we think of as a "case view" with an "aggregate view." By this, we mean that it is important for students to bear in mind their own experience with plants, and especially their own plant – what they know in particular about how it looked and how it changed – as they begin to notice and interpret patterns in data that describe a group of plants and eventually, plants of this kind in general (a population that they will never directly observe). Coordinating these views is very challenging, and achieving that coordination necessarily requires shifts in focus of attention among these levels. Our hope was that, ultimately, students would learn to anticipate how a change at one level of description (for example, the lifecycle stage of a group of plants) would be reflected in change at a different level of description (the shape of the data in frequency graphs that described the heights of all the plants at the beginning, middle, and end of growth).

Plants were directly at front and center ("on the table, so to speak") as instruction was initiated and in fact, students were continually engaged in activity directed toward answering questions about the effects of light and fertilizer on growth. As students later learned, increasing the fertilizer does not make plants grow taller, although their canopies were affected. The mean differences of the two samples were entirely consistent with chance variation, a form of variability extensively explored later by the class. So the data students were considering tended to disconfirm their prior beliefs, a situation known to make reasoning more challenging.

As these investigations were framed, plants and the abiotic factors that affect their "health" were the primary motivating concern. Shortly thereafter, by deliberate intent, the plants began to participate in a number of cycles of moving from foreground to background of the class's attentional focus – the actual plants and their mathematical qualities alternating as the central topics of the class's consideration. The episodes analyzed by the chapter authors occur during one of these shifts away from plants as center stage toward data and their qualities. As instruction continued, we and the teacher worked deliberately to bind the connections between these two worlds so that looking at a graph (or a display of quartiles) *became*, to them, looking at plants (a phenomena that Nemirovsky, Tierney, & Wright, 1998, refer to as the "transparency" of a display). This lift from phenomena to various forms of representation (that ideally "talk" to each other) is negotiated by professionals (Latour, 1999), and it was a form of practice that we were attempting to introduce to students.

The initial shift from plants to their mathematical qualities occurred as students puzzled over a question that initially seemed straightforward: What does it mean to measure growth? Identifying *attributes* that can be measured means not only emphasizing qualities like height, width, or number of leaves; it also means ignoring other qualities. Our students agreed that height is an important attribute to track if one is interested in documenting plant growth, but this did not settle the issue: a considerable amount of discussion was devoting to agreeing on what we meant by *height* in this case. Some students noted that Fast Plants often grow more than one stem. Which stem should be measured as an index to the plant's overall height? Others pointed out that although some parts of the plant are visible above the ground, some remain under the ground and cannot be seen. Accordingly, there was a debate about whether height should be measured from the top of the soil or from the bottom of the pot. In many cases, plants lean as they grow. Students wondered whether stems should be straightened before they were measured or whether "height" meant the tallest part of the plant in its leaning posture. Moreover, these students had already received (in previous grades) extensive instruction on the theory of measurement. If they were first graders, it might have been necessary to conduct further extensive work on the very idea of abstracting height as a quality of plants that can be partitioned into equal units (youngsters often rely on direct comparison). From their earliest decisions, then, the students were vacillating between attending primarily to what they knew about plants and what they knew (or could figure out) about quantities.

As our colleagues noted, the graph episodes in the Allerton excerpts involved data on the entire class's set of 63 plants near the middle (Day 19) of their growth cycle. It is true that at this point, the class's discussion was primarily about the displays themselves and how they could be organized to substantiate claims about the height of a "typical" plant and the variability in heights of plants. However, we would claim that it is *because* the plants in fact had *not* disappeared that this idea of a typical plant turned out to be problematic. One of the things we learned from this design study was to appreciate the conceptual difficulty of understanding the idea of natural variation (as opposed to, for example, measurement variation, which the same students considered entirely sensible). Asked to suggest a typical height of their plants, students were genuinely flummoxed. As one of them objected, "It can be any height. *All* the heights are *equally* typical." Struggling with this idea of typicality made sense to students once they began to consider what they would expect to see "if you grew them again." When students considered this question, the plants re-appeared in conversational turns. This suggests that they were never (conceptually) far afield. As Thompson, Liu, and Saldanha (2007) point out, one of the intricacies of statistical reasoning is coming to understand that the entire edifice (from a perspective of conceiving of chance as frequency) is founded on construction of a repeated, random process. Hence, for us, the conversation around what would happen if we grew the plants again was critical (and intended in the design).

On the basis of sampling investigations, students concluded that some plant heights – those toward the center of the distribution – would be more likely to recur in subsequent rounds of growth, whereas others would be less likely. The earlier notions about "typicality" and "spread" now were taken up and used as lenses for thinking about the distributions of the samples and then of the sample means. We agree that seeing *through* the displays – so that one sees plants and not just numbers – is the game. However, we remain pretty convinced that this is an accomplishment to be achieved and planned for carefully. In sum, we agree with Confrey: "There are times to learn what tools are by using the tools, and there are times for extending the tools themselves through observing and concentrating on them" (p. 18).

One might argue that this set of expectations constitutes a misguided or overly directive view of education. From some of our colleagues, we received the impression that they believed learning should be driven largely by students' interests and chosen directions, and that with the right tasks and respectful support, students will spontaneously choose fruitful directions for their own learning. Our view is that this is a stance that works well only when one's involvement in a child's education is relatively brief. We find it insufficient for guiding students' disciplinary knowledge and reasoning over multiple years. Students' interests and direction need to be honored and cultivated, but also to be challenged and stretched – from somewhere to somewhere. As McClain (Chapter 7) points out, an adequate view of development requires an adequate theory of assistance, one with a sense of direction that also includes some knowledge of a variety of ways in which students might move forward. These commitments do not need to entail a rigid, overly determined agenda.

The evidence from end-of-unit interviews suggests that students learned many of the ideas about statistics that we were targeting, and in particular, that they made important strides in representational fluency and in making informal inferences about differences between populations by reference to the likelihood of these differences in light of repeated, chance processes (Lehrer & Schauble, 2004). Students can (and do) accomplish much more than they are usually asked to in school, and moreover, we think that having conceptual tools like these at their disposal is part of what it means to provide a liberating education. We emphasized distribution as a tool for thinking about relations between organismic and population levels and signaling biological growth processes. Helping students develop tools like these equips them to conduct legitimate investigations of their own questions about nature. In school science, teachers and curriculum designers frequently constrain classroom work to those investigations in which the results are easily interpretable with the students' usual mathematical repertoire. In practice, what this means is that students are limited to explorations in which the answer is already well known and the phenomena are limited to those that reliably generate differences so dramatic that interpreting them provides little challenge. In fact, many designers of science curriculum ensure that experiments "properly conducted" result in nonintersecting distributions of outcomes. Perhaps this is an unjustified constraint on students' understanding of science. It is neither desirable nor necessary to limit science education to "canned" investigations or to cut off opportunities for students to conduct research on questions that arise from their own interests. For this reason, we regard data modeling, in general, and distribution, specifically, as critical intellectual tools for science education.

We also remain convinced that there is significant educational value in emphasizing data representation. Rather than first presenting students with representational conventions and rules about how to use them, we encouraged students to invent their own representational solutions and then to evaluate the resulting displays against their own evolving criteria for communicability and mathematical precision. Rather than building toward a limited repertoire of adult-imparted representational conventions and a brittle sense that some are "right" whereas others are "wrong," we wanted students to develop a more nuanced notion of design trade-offs, including the recognition that all representational features have both advantages and limitations. This understanding of the purposes, opportunities, and challenges of representation is a way of coming to understand the natural world, for both children (e.g., diSessa, 2004) and for scientists (e.g., Latour, 1999). During the intervals analyzed, we noted the invention of many forms of representation, sufficient to prompt consideration of how designers' choices influenced the shape of the data.

We close with a final word about variability (and yes, we do find it ironic that variability was also the topic of the investigations students were pursuing here). Following children across several years and educational contexts tends to enforce humility about drawing generalizations that are not sensitive to how widely student behavior can vacillate across different contexts. For example, a student in our participant group who was labeled as learning disabled in one class become a math star in a subsequent year, and then lapsed back again to being an indifferent student in the grade that followed. Conclusions about his mathematical capability in any of these three grades would doubtless seem surprising to his teachers in the other two. We continue to be surprised about things that seem obvious in the moment and then, far from obvious the next moment. Education is not a very rule-driven enterprise, but over time and with a sufficient number of samples of experience, one begins to see patterns in the development of students, of teachers (and probably, of researchers). We thank our colleagues for joining with us in seeking out these patterns, and we hope that with persistence and effort, we all make progress on this thorny issue of time and embedded histories.

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Chapter 22
Cultural Forms, Agency, and the Discovery of Invention in Classroom Research on Learning and Teaching

Rogers Hall

> *You can do anything you like, but the cost is high. The more you want to depart from the standard package, the more you find that everything else connected with making music [statistics] has gotten more complicated and difficult. You will have to recruit and train people who otherwise would have been ready to go, you will have to learn new ways of doing things, you will have to construct machinery or adapt it to your purposes instead of being able to use off-the-shelf products. All of that will eat into the time and resources you might have devoted to making art [statistics], which is what you set out to do.*
>
> (Becker, 1995, p. 306, [statistics] added)

> *Rather than first presenting students with representational conventions and rules about how to use them, we encouraged students to invent their own representational conventions and then to evaluate the resulting displays against their evolving criteria for communicability and mathematical precision*
>
> (Lehrer & Schauble, 2004, p. 669)

This paper and commentary is about cultural forms, how agency is frozen into and circulates through them over historical time, and how these processes are relevant for design-oriented studies of classroom learning and teaching. Becker (1995), writing about the costs of being an innovator in the classical music business, frames a lone innovator (Harry Partch, a creator of micro-tonal compositions, instruments and performances; see http://www.harrypartch.com/), who breaks with the "standard package" of Western classical music and consequently spends a lifetime building instruments and training players to perform his compositions. Lehrer and Schauble, writing about the inventions of mid-Western 5th graders conducting experiments with Wisconsin Fast Plants® (a past-time invention in the genetics of disease resistant agricultural plants; see http://www.fastplants.org/), frame a group

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of self-directed classroom investigators, who search for representations of plant growth that are mathematically precise and easy to communicate with their peers.

These are radically different ways of thinking about how the work of innovation – the invention and stabilization of cultural forms – is assigned to people and things over time. In Becker's treatment, Partch and his followers' inventions lead to a life-long struggle against (or around) Western conventions. In Lehrer and Schauble's treatment, 20 or so 5th graders manage to invent workable statistical displays over a period of a few weeks.[1] For Becker, the standard "package" (p. 304) of making (and listening to) Western music is massive (Akrich, 1992) – there are many people and many productions, bound together in mutually accountable relations of authoring, performing, and listening – and this mass presents substantial inertia to anyone hoping to make music differently. For Lehrer and Schauble, the scale and timeline of inventing statistical displays are comparatively lightweight, playing out inside a single classroom, repeatedly, within a single school year. Learning through invention (or innovation) is a relatively recent discovery in the learning sciences (more on this later), but it is a long-standing problem in the sociology of science. If in Becker's account, Partch were to succeed at scale, or if in Lehrer and Schauble's account, 5th graders arrive at precise and persuasive statistical displays, their agency would need to be frozen into and then circulate through new cultural forms. The delegation of agency through circulating cultural forms and "invention" as a way to arrange for this in mathematics classrooms are the broad topics of my chapter and commentary.

Across the arc of work that makes up this edited collection, authors have produced diverse answers to the question implied by this corpus of materials – What is this a case of?[2] Initial analyses by authors of target chapters were updated, after being criticized and extended by commentators. And in this process, corpus materials were indexed and transcribed more fully. As analysts and authors learned more about the social history of instruction in the classroom studied by Lehrer and Schauble (their introduction, Chapter 2, this volume, was one of the last drafts received), what these materials have come to be "a case of" has expanded.

Now at the end of this arc of work, target chapters still take up productively different analytic stances towards the corpus materials: Jim Wertsch and Sibel Kazak (Chapter 9) focus on agency built into potential uses of historical tools like graph paper; James Greeno (Chapter 3) focuses on how adults position learners to experience different kinds of agency (disciplinary versus conceptual) as they participate in classroom talk; and William Clancey (Chapter 15) focuses on how meaningful activity emerges from transactions within ensembles that put people and things into coordination. These are conceptually diverse adventures within a common corpus of classroom video recordings. Although the target papers take us in different analytic directions, each also delivers a directly normative evaluation of where this classroom is headed: Wertsch and Kazak find it unlikely that middle school students will "discover" complex historical forms, like histograms, during short periods of instruction; Greeno finds that adults do most of the work of reconciling students' ideas towards a desired instructional form (the histogram), so chances for learning with conceptual agency are reduced; Clancey finds that the use of statistical tools (like a histogram) is almost entirely severed from an actual context of inquiry these tools might serve (growing plants under a planned, experimental contrast).

Each of these authors' analyses, including their evaluations of the classroom against some normative model of proper instruction, rest on how they have assembled an understanding of the "social history" (Scribner, 1985) of the Lehrer and Schauble research classroom, as an environment for learning and teaching. How do moments of interaction, utterances and the like, fit together to make up activity that is relevant and meaningful, perhaps in different ways, to participants over time? Any author writing in this book faces a similar challenge, so I will begin my commentary by describing my experience with the corpus, across the arc of work that makes up this book. The social history of learning and teaching that I assemble reflects the luxury of writing after the target authors made their initial (and updated) forays into the corpus of recordings, so being able to learn from what they found. My efforts also reflect several years of ongoing conversation with Lehrer and Schauble, in the context of research on learning statistical modeling. I see the classroom documented in their corpus, and rendered differently in each analysis, against my own history of mutual engagement with them on research in other classrooms and workplaces, but with a common focus on what they call "data modeling" (Hall, Lehrer, Lucas, & Schauble, 2004; Hall, Wright, & Wieckert, 2007).

I would like to investigate the larger context within which cultural forms, agency, and ensemble performance are said to constrain and enable meaningful activity and learning. Doing so will lead into the larger activity system of this classroom and the Lehrer and Schauble (henceforth L&S) design experiment. If children can be said to be inventing something, so too are L&S. Their experiment involves moving against what Becker would call the standard package of mathematics and science teaching. And their project is part of a larger social/research movement in the learning sciences that takes a decidedly non-standard approach to these activities.

Some Prospects and Problems for Secondary Analysis of Learning and Teaching in Video Recordings

Before addressing target chapters in more detail, I feel obligated to describe my own experience with the L&S corpus. This volume is an example of an effort to conduct systematic, secondary analysis of a shared set of video recordings of teaching and learning, but there are others. Tim Koschmann (the current editor) organized an earlier effort to conduct multiple analyses of a problem-based learning episode recorded in a medical school (*Discourse Processes, 27*(2), 1999), in which I participated as an analyst; Kay McClain (Chapter 7) organized a similar effort around records of her own teaching of elementary school statistics (*Journal of the Learning Sciences, 11*(2&3), 2002), for which I served as a reviewer. While somewhat more common in linguistics, secondary analyses of corpus materials are still rare in the learning sciences (see McWhinney, 2007, for futuristic proposals to support "collaborative commentary"). All these efforts might trace their roots (but typically do not) to the Multiple Analysis Project (Grimshaw, 1994), a 20+ year effort to complete multiple analyses of a doctoral dissertation defense, or earlier still to an as yet unpublished report, *The Natural History of an Interview* (NHI; see McQuown, 1971; Leeds-Hurwitz, 1987), on an effort by a group of interdisciplinary scholars to analyze the interactive environment of a psychiatric interview. In each case, analysts bring different theoretical perspectives to the same empirical materials, and their findings are interesting individually and by comparison. Given this prior history, some of which I encountered while finishing this commentary,[3] I opened the corpus of materials with great interest.

The invitation to comment on target papers came with a DVD containing three folders (Fig. 22.1, left; Days 27, 28, and 29, later renumbered as Days 26, 27, and 28, which I use throughout), each holding a digital video recording of instructional activities, a notes file, and a series of "Exhibits" or data displays (Day 26, only). For reasons of software incompatibility, I could view only the first day's video recording and part of another (I obtained all three videos and transcript *after* the workshop), and I could not view any of the notes or data displays. I was able to read all the target papers. This was a rocky start for my attempt to navigate in an unfamiliar corpus of video recordings, but I do not mean to lodge a complaint. Since secondary analysis has been rare in the learning sciences, there is value in being clear about the difficulties of carrying one off.

What does it mean to have (or not to have) an index when setting out in a corpus like this? On the right in Fig. 22.1 is a pair of images from a study of the history of the Museum of Vertebrate Zoology (MVZ) at UC Berkeley (Griesemer, 1990). The tags were written by curators in indelible ink, in a format that was standardized in the early 1900s and is still in use for indexing specimens (skulls, skeletons and skins) to field notes (far right in Fig. 22.1) about habitat in the museum's collection. The MVZ and its collection are a case study in Star & Griesemer's (1989) widely influential analysis of how "boundary objects" can be designed to help coordinate divergent interests of groups in technical and scientific work. In the case of the MVZ, trappers, philanthropists, curators, and biological researchers were able to coordinate around the collection, even though none of these groups saw it in the same way. Even more important for our purposes, Griesemer (1990) points out that a suitably indexed collection of material specimens and field observations, like those found in the MVZ, can serve as a "remnant model" for researchers who may bring different theoretical perspectives to the collection:

> "Remnant models," i.e., material models made from parts of the objects of interest, [. . .] are robust to some changes of theoretical perspective because they are literally embodiments of phenomena. If these embodiments are preserved, they may be studied again and again under different perspectives. [. . .] Changes of theoretical perspective about the nature of species can be taken into account by pulling the specimens back out of the drawers or off the shelves and reanalyzing the model in terms of a different set of taxonomic designations. (Griesemer, 1990, pp. 80–82)

The materiality of the specimens, when coordinated with symbolic descriptions, allows for analysis from different theoretical perspectives. This is the exactly the promise of a corpus of video recordings,[4] like those analyzed in this volume, and

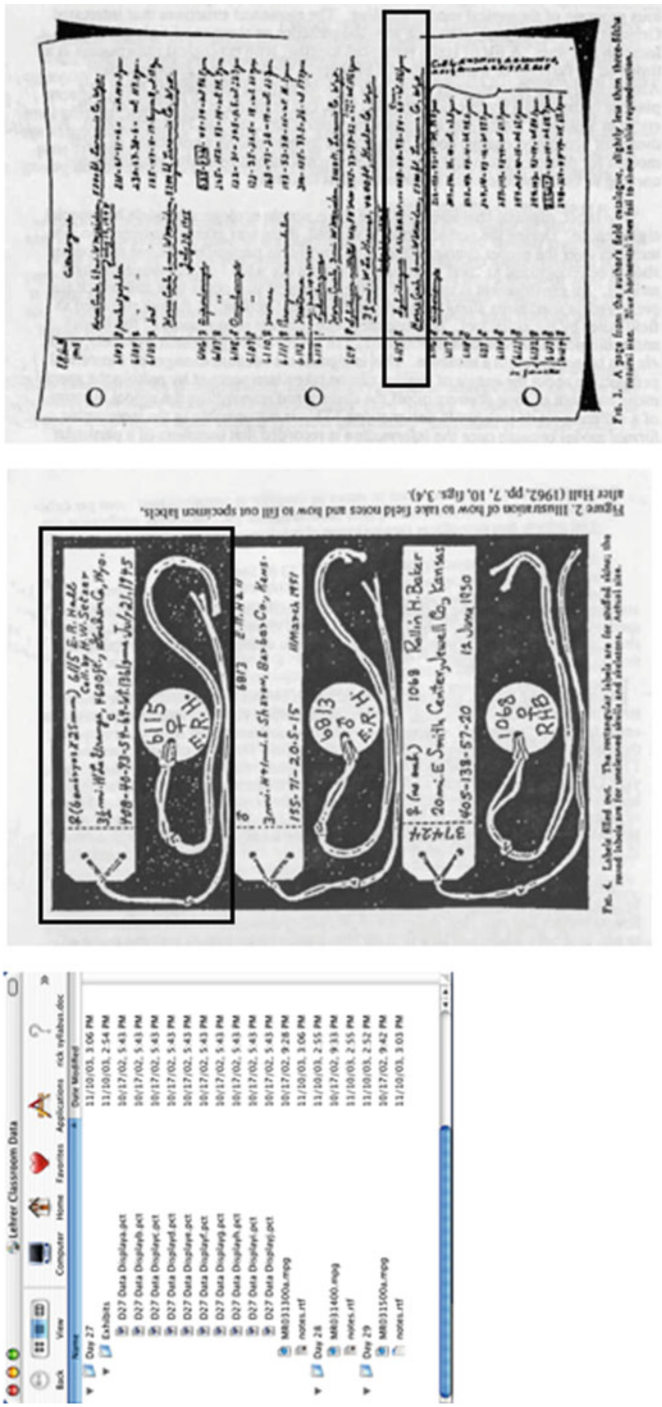


Fig. 22.1 Indexing schemes for "remnant models"

this is also why indexing the materials (video and audio records, documents) to the context in which they were recorded matters enormously. In the case of the MVZ, a specimen without a tag that permits retrieval of a field note is at best "just dead meat" (Star & Griesemer, 1989, p. 401), and more threatening, an object at loose in an otherwise orderly, material model of habitat-species relations in California.

Back to my experience with the meat... Day 26 starts with what appears to be an ordinary middle school classroom (Excerpt 1 in Appendix B). The teacher sets a task for groups of students seated at local tables, but almost immediately, he invites "Rich" to ask a question about how students should organize their data [Excerpt 1: Day 26, 0:00:07]. As the video progresses, four adults other than the teacher drift in and out of camera view, asking students questions or sitting at local tables and working directly on the shared task (researchers Rich Lehrer and Leona Schauble appear to lead this activity). At least one other adult (never seen) operates a camera and a boom microphone. The video record is not continuous, both moving from group to group and skipping over segments of activity that are of indeterminate length (i.e., the record is interrupted in real time, jumping ahead in time, at adjacent video frames). In this sense, the video record resembles a "dub tape," in which selections from an original (presumably continuous) recording have been edited together to show something. The video record foregrounds activity of students working at group tables, but this larger backstage of adult production is itself a complex activity system.

While I could not initially read them, the "notes" files (Fig. 22.1, left) are an important contextual resource, critical for understanding the larger backstage, and they build on one another. The first is a set of notes from March 13 (the relation to the day-in-unit was still not clear), written by a graduate student who worked with one student group on the idea that "typical" heights should be found where a large percentage of plants fall in the distribution. This note ends with expectations for the next class meeting, in which students will compare different groups' accounts of what is typical. The second notes file is a nearly verbatim transcript, made by Leona Schauble (LS)[5] on March 15, that ends with "reflections" on how what students did last year (a "rockets study") did not carry over to the plant growth study. The third file is a review of the unit, written by the teacher, which incorporates observations and transcript (evidently from LS's notes) across multiple days. These notes make it clear the 3-day corpus comes from a much longer classroom research study, in which the teacher and a team of researchers collaborated intensively, over 2 years, to help children understand data analysis and statistical concepts.

I will have more to say about this classroom research study, as it exemplifies "invention" (pace Becker and Partch) at multiple timescales, but it is important here to point out that the target chapters in this volume, as well as most of the commentaries (including my own) were conducted and written without any further contextual information about the classroom depicted in three, selectively edited video recordings. The target papers, commentaries, and cycles of revision have substantially enhanced all of our understanding of these 3 days. They have also incrementally built up a substantial index or map of what students and adults were doing during classroom events in the video recording. I think of this as an incremental "mapping" effort, and there were many uncertainties (e.g., determining which displays were authored by which groups, reflecting which individual's "ideas" or "inventions" during these 3 days). Several months after the Allerton conference, Lehrer and Schauble submitted a journal article (published 7 months later, in 2004) analyzing what students learned about "data modeling" (p. 636) in this plant growth study. In this sense, the context for the collective effort of secondary, multiple, or "collaborative analysis" (McWhinney, 2007) just keeps on coming.

The larger issue concerns the mobility of context (pre-theoretic, as Griesemer would have it for "remnant models") as it allows secondary analysts to frame questions, to fully understand activity depicted in the corpus, and to arrive at findings that may diverge from what is claimed by primary analysts (in this case, Lehrer & Schauble as providers of corpus materials; henceforth L&S). That the authors of target papers in this volume used the corpus in very different ways may reflect tensions associated with the availability and mobility of context. Wertsch and Kazak (Chapter 9) select two excerpts of group work (from Day 26) to *illustrate* how cultural artifacts allow us to "say more than we know," and more important, to get on with joint activity despite very different intentions and levels of understanding. Greeno (Chapter 3) selects multiple strips to *exemplify* how classrooms provide spaces for authoring "positional identities," and he then performs an explicit *comparison* with two other classrooms. Clancey (Chapter 15) effectively *inhabits* the corpus, initially ranging over 3 days of life in the classroom (including careful attention to people in the margins of the focal activity), and only later returning to the beginning of the fast plant description task with a sense of who the players are and what is to come.

For a secondary analyst, there is a difference between discovering something that is in the corpus and something that is not. In the first case, other analysts or readers might agree or disagree, and everyone can be pleased with the outcome. But when critical, contextual information arrives after secondary analysis is well underway, there can be trouble. Inferences may need to be retracted or revised, and the "descriptive adequacy" (McDermott, Gospodinoff, & Aron, 1978) of accounts given by secondary analysts is always in question. Again, this is not a complaint about the L&S corpus or the activities leading up to this volume, just an effort to make the risks of investing in secondary analysis, for both primary or secondary researcher, visible.

On "Saying More than You Know" and Hearing More than Is Said with Graph Paper

Wertsch and Kazak's target chapter (Chapter 9) provides an elegant illustration of the role of cultural forms in conversations where people learn. They focus on graph paper as a cultural form that already has a substantial measure of agency "frozen in," so to speak. To do this, they develop and illustrate what they call the "Vygotsky-Shpet approach." The idea is that cultural forms provide constraints and affordances that allow learners to "say more than they know." At the same time, and by a slight extension of their argument, we should expect these same cultural forms to allow more knowledgeable others (a teacher or researchers, in this corpus) to "hear more than is said" concerning what learners understand as they struggle to solve problems in tasks presented to them by adults.

Wertsch and Kazak's analysis of frozen agency is elegant, but as other chapters in this volume demonstrate, the classroom environment in which graph paper exercises its powers is productively messier than their analysis suggests. Is this mess just more of the same, in the sense that students could invent statistical displays by unioning together the constraints and affordances of a legion of other cultural forms? Wertsch and Kazak do not rule this out, and desks, chalkboards, wall posters, Fast Plants, and other artifacts are certainly available for analysis. Or is there structural regularity in the mess that is meaningfully and consequentially more complex (both for participants and analysts, looking in)? Wertsch and Kazak illustrate the operation of already frozen agency for graph paper.

Wertsch and Kazak illustrate how the dimensional structure of graph paper supports thinking and talking about how to organize plant height data, using two episodes selected from the first of 3 days in the L&S corpus of classroom video recordings (Day 26). In these episodes, they examine the use of graph paper that was distributed to groups of students with a directive from their teacher to "organize the data in some way" [Excerpt 1, 0:00:07]. Data were posted on a large sheet of paper at the front board in an unordered list of "Fast Plants" heights, measured by students in an ongoing classroom experiment to compare plant growth under different lighting conditions. Students were also asked to find the "typical height" of a Fast Plant in the list, and to find how "spread out they are" when the plants were taken as a collection.

In the ensuing activity and conversations, Wertsch and Kazak argue, sheets of graph paper play a key role as, "mediational means, or cultural tools that are used at varying levels of dialogic intersubjectivity" (p. 153). By this they mean that graph paper (rectangular, desk-sized sheets of white paper ruled with equal-area squares) both affords and constrains particular meanings when used to order the listed data. Wertsch and Kazak compare data ordering efforts conducted either between students and adults (their first selected episode) or between student peers without adult intervention (second episode).

Their Vygotsky-Shpet approach to semiotic mediation focuses on, "collision and conflict between a sign vehicle, whose meaning tends to abstract and generalize and belongs to an ongoing semiotic community, on the one hand, and the unique, spatiotemporally located intention of the individual, on the other" (p. 155). Wertsch and Kazak appropriate from Vygotsky the idea that word meaning, as a unit of conscious experience, arises when thought is expressed through the cultural form of words. From Shpet, who was one of Vygotsky's teachers and himself a student of phenomenology, they appropriate the idea that thought, which is relatively continuous or seamless as experienced, is "articulated" and so shaped into discrete units by expression in words. Words both selectively abstract from thought and give shape or structure to thought. In just this sense, users of cultural forms (like words or graph paper) can "say more than they know" by expressing their thoughts in shared cultural forms.

But the approach extends beyond individual experience in important ways. Because the potential meanings of a sign form already exist in a semiotic community, use of conventional sign forms in instruction, “amounts to a sort of ‘taming’ or ‘domestication’ of novices’ interpretations of the world” (p. 155). In other words, the use of cultural forms by learners (novices) may fall well below or outside the conventional, skilled use of these forms by knowledgeable participants in the community. Through instruction, specifically conversations with peers and more knowledgeable adults, learners’ uses of cultural forms become more conventional. At the same time, their thinking and consciousness are shaped by meanings that circulate in the community. In this way, thinking is domesticated by the use of cultural forms. Wertsch and Kazak further argue that some forms, “are incredibly robust in that they can allow interpretation and understanding at many different levels yet still support the intermental functioning required to move learning and instruction along” (p. 156). While it is common to think of student–teacher interaction as a zone of proximal development for learners, Wertsch and Kazak remind us that cultural forms like words and graph paper play a similar role in supporting learners and their conversational interactions with teachers.

Wertsch and Kazak discuss still other implications for the development of expertise in collective activity. Within a community, the distribution of conventional skill or expertise can remain uneven, since high levels of performance by a few individuals may be sufficient for collective purposes, without a wide spread in skill or competence among most members of the community (Nardi, 1993). One consequence of this view is that there may be many mundane users, a few relatively skilled users, and a very few makers of cultural forms. As Wertsch and Kazak put it,

> Most of us probably speak, calculate, and carry out other semiotic action most of the time without understanding the full power of the sign systems we are employing. In the famous image of Edward Sapir (1921), it is as if we are harnessing a dynamo capable of generating a huge amount of electricity just to power a doorbell. (p. 156, Sapir cited in Chapter 9)

The consequences for learning in this approach are fairly conservative, by my reading. Whatever level of analysis one chooses when employing the Vygotsky-Shpet approach, all paths eventually lead to Rome (conventional statistical displays). In interaction with others and cultural forms, people go along and get along (micro genesis), eventually acquiring a conventionally structured, historically-specific, individual consciousness (ontogenesis). At a collective level of analysis, existing cultural forms circulate and acquire their users (sociogenesis; see Saxe, 2002). As Wertsch and Kazak put it regarding what might be learned,

> the bottom line is that no amount of exploration on the part of novice students will yield the discovery of things like graph paper and histograms. These are historically evolved cultural tools, and the goal of instruction is for students to acquire mastery of them. (p. 165)

While the force of things (cultural forms) on thinking and interaction is nicely illustrated, this approach does not describe or explain innovation or discovery of new cultural forms, how they spread, or how collective practices change.[6] Nor does it help us understand why learners might find it engaging to participate in collective activities, particularly where these are designed to domesticate their thinking (i.e., a narrow view of schooling). In the remainder of this section, I hope to extend Wertsch and Kazak's analysis in these directions.

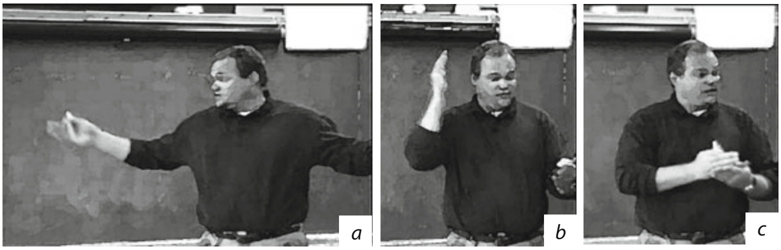
Since relatively little context was available to Wertsch and Kazak, it is understandable that they would not attend to prior history in this classroom or to the pedagogical design that was in progress before, during, or after 3 days of video clips provided in the L&S corpus. By combining the video record with Lehrer & Schauble's (2004) fuller report, we can further explore the development of data displays, including the role of graph paper, by looking back and forth along this larger, connected timescale. For example, Wertsch and Kazak notice that the classroom teacher likened the day's task to a "thing before with rockets," then offered "Rich" (Rich Lehrer) a speaking turn to ask questions [Excerpt 1, 0:00:07]. The video record does not include RL's full response, but as reported in (Lehrer & Schauble, 2004), the majority (19 of 21) of students in this 5th grade classroom participated in a rocket launching experiment the year before. In that classroom design experiment, reported in Petrosino, Lehrer, and Schauble (2003), students were taught to make and read data displays in which observed values were listed within ascending bins or intervals (see Fig. 22.2). By preserving case values, these displays resembled "stem-and-leaf" plots (Tukey, 1977), a term that was used by several students and the teacher in the 5th grade classroom (the corpus of materials for this volume). Conversations between students and adults in this corpus would be understood, certainly by adults and at least some students, in terms of this prior history of instruction.

There is also striking evidence in the video record that graph paper does not act alone, even if one sets aside prior project history. For example, while writing questions about typicality and spread on the board, the teacher demonstrates what he means by "spread out" in the gesture sequence[7] shown in Fig. 22.3.

These contrastive gestures may[8] have provided students with (a) an image of the data cases, ordered from low to high, (b and c) a dynamic simulation of center, enacted as a forceful cut in the middle of ordered values, and (d through f) a contrastive simulation of "spread" as a wide or narrow observed range. In this sense, graph paper circulates in a semiotic and historical environment that is already rich with possibilities and expectations (at least on the part of the teacher and researchers). Within the first few minutes of the video record, activities from the prior year were recalled, the teacher dynamically illustrated center and range, and students asked critical questions about the relation of an unordered data list to their prior activities.

6	7	8	9	10	11	12	13	14	15
6.2	7.8	8.7	9.1	10	11	12.3	13		15.5
6.4		8.8	9.2	10.2					
6.8			9.3	10.3					
			9.7	10.6					
			9.8						

Fig. 22.2 A data display showing student measures of the height of a flagpole



MR: Yeah, ((*a*))how spread out. MR: So (.) do they ((*b*))all ((*c*))fall at the exact same point?

MR: Or ((*d*))does it ((*e*))seem like there's a ((*f*)) range the plants can fall in. = How spread out are they? ((*turns to board*))

Fig. 22.3 The teacher shows what he means by asking/writing, "How spread out are the heights?" (Excerpt 1)

On Being Positioned to Learn with Conceptual Agency While Representing Center and Spread

Greeno (Chapter 3) advances a situative perspective on learning, using ideas from Lave and Wenger's (1991) theory of situated learning (e.g., learning through legitimate peripheral participation in disciplinary practices), and extending these by asking how learners are positioned to take different types of agency in representational practices. His analysis uses the corpus to explore opportunities for learning with *conceptual agency*, in which students learn to use representational forms to pursue their own questions (e.g., in the L&S corpus, finding a way to describe a "typical" fast plant, given a varied collection of individual plants). This contrasts with opportunities for learning with *disciplinary or material agency*, in which students learn to recognize and manipulate forms or materials that make up the conventional representational infrastructure of a discipline (e.g., building a histogram from observed data in conventional statistical analysis and modeling). According to Greeno (see also Boaler & Greeno, 2000; Hall & Greeno, 2008), both conceptual and disciplinary agency are required for learning the practices of a discipline, though traditional instruction typically focuses more on learning with disciplinary or material agency.

As a theoretical project, Greeno seeks to integrate two aspects of learning that are usually treated separately: (1) *systemic* aspects of social interaction and relations between people in classroom activity – how learners' participation in activity is structured over time, with (2) the *coherence* of information structures that are produced in and circulate through these activities. Greeno proposes that any adequate theory of cognition and learning must deal with learners' positioning – systemic relations between participants, involving different types of personal agency – and the coherence or meaning of information contributed by individuals and held in common ground. Hoping to step over polarizing assumptions that pit individual against social and information against activity, Greeno argues, "activity [is] jointly systemic and semantic 'all the way down,' so that whatever the size of an event we choose to analyze, the appropriate analysis will include principles of both informational and interpersonal interaction that function at that grain size in order to explain the event" (p. 48). Individuals learn in activity systems where they create and share common ground, get into alignment with others around collective goals, and make contributions by participating in representational practices that are also changing over time.

Greeno compares learning arrangements in the L&S classroom with those found in two other classroom research efforts, both involving middle school students and instructional activities designed by researchers. From these other classrooms, he presents two comparison cases (Whales, Guppies; see Engle, 2006, and Jurow, 2004, respectively) in which students are positioned to have agency both for problematizing and resolving questions of representational *coherence* (i.e., whether representational forms capture meanings relevant to pursuit of shared goals). The Whales case is analyzed at the level of adopting tasks and accomplishing goals over multiple weeks, while the Guppies case is analyzed at the level of emergent understandings for tasks that last from a few minutes to a single class period. In both, Greeno conjectures there is a "threshold for problematizing" (p. 51) when participants make proposals for representations or strategies, and this threshold is governed by how the participation structure of the surrounding activity sets expectations about the strength of common ground when students take a decision. For example, in participation structures where students have comparable rights to make contributions and to guide joint activity, strong grounding would be preferred, so any member of the working group could challenge a proposal. In contrast, in a more hierarchical participation structure, where some participants dominate and others follow or are relatively disengaged, even weak grounding could win the day.

In his analysis of selections from the L&S corpus, Greeno needs to extend his threshold conjecture to distinguish between how students and adults are positioned with agency for *generating* alternative representations, and then also for *reconciling* among these alternatives. In the Whales and Guppies cases, Greeno argues that students had conceptual agency for both generating and reconciling alternative representations and strategies. But in the L&S corpus, Greeno finds that students primarily have agency for generating alternative representations (e.g., a case magnitude plot versus a histogram), while adults (the teacher and research team) lead the activity of reconciling which of these forms is most useful for describing a typical fast plant. As a consequence, Greeno argues, students' opportunities for exercising conceptual agency are limited as they learn about statistical analysis and modeling.

The teacher (and research team) give the task of creating a representation that shows center and spread, and how this task relates to a plant growing experiment is never fully explained. The combined data list may erase classroom history for some students and even shift the meaning of their prior activities – from multiple data sheets to a single list, from personal measurements to aggregate data, and from plant growth to rocket launching. While shifts presented in the new task may be substantial, they do not appear to be unprecedented. As I understand the L&S corpus, the history leading up to this task has been carefully arranged, and it is within this prior classroom history that graph paper circulates, or that alternative representations are seen as powerful or useful. So in looking back within the available history, we find evidence of prior cycles of collecting and displaying data with variability. There is a consistent effort to remind students of this history and to give them clues about what "typical" and "spread" would look like in a data display they are asked to make.

Looking forward at where teachers, researchers and students might think this activity is "headed," the in progress design experiment involves "inventing" data displays for common data and questions, then using local work by student groups to set up a "discussion" (Orsolini & Pontecorvo, 1992). Variation in local work is harvested to discuss why some displays are better than others for answering specific questions about "typical plant height" and "how spread out" the data are. In the local interactions analyzed closely by all the target chapters (Groups 2 and 3, Day 26), adults play very different roles in helping students use graph paper to create this prospective variation in displays.

In Group 3, initial work to write data values in separate cells of the graph paper is interrupted by an adult researcher (LS) and redirected towards creating a "frequency chart" that (as LS puts it) students have used before [Excerpt 4: 0:24:24]. Wertsch and Kazak characterize LS's conversational moves as an attempt to domesticate or to "rein in the students' seemingly aimless wandering," and I was struck by this image of driving students (like wild horses) towards a conventional statistical display.

There was a time, of course, when graph paper was not yet in wide circulation, and forceful directives were appropriate or even required for its use by otherwise experienced scientists. In a paper on observing stars, written for fellow astronomers in 1833, John Herschel recommends,

> Let a sheet of paper be procured, covered with two sets of equidistant lines, crossing each other at right angles, and having every tenth line of each set darker than the rest. By these, the whole surface of the paper will be divided into large squares [. . .] Such charts may be obtained, neatly engraved; and are so very useful for a great variety of purposes, that every person engaged in astronomical computations, or indeed, in physico-mathematical inquiries of any description, will find his account in keeping a stock of them always at hand. (p. 178; quoted in Brock & Price, 1980)

Returning to the more contemporary directives by LS to students in Group 2, when is enough history enough? As Lehrer and Schauble (2004) tells us, and as LS (then) already knew, these students had been taught to make displays that involved showing the frequency of cases in binned intervals the year before (Fig. 22.2). And as I asked in my original comments at the Allerton conference, "Who here can tell us what are the consequences for being caught doing IRE[9] with children in public?" There was a long silence during which (I inferred) no workshop participant wanted to join LS in the second turn position. Now understood against the prior history of this classroom (i.e., the rocket project, explicit instruction on displays that show the frequency of binned cases), my sympathy for LS has only grown. How could these students, who as 4th graders were able to organize data on the height of rocket launches or a flagpole, now propose to put each plant height value in a separate cell of the blank graph paper?

Wertsch and Kazak also use an excerpt of work by Group 2 to illustrate their Vygotsky-Shpet approach. In this group, early work without adult guidance appears to be moving towards a "case magnitude" display (i.e., values with bars for heights, ordered low to high; Lehrer & Schauble, 2004, p. 648). But as RL's later questions make clear, students within Group 2 intend to create very different displays (see Excerpt 5). One candidate is a case magnitude display ordered by plant names/labels proposed by Jewel and subsequently erased; a second is a case magnitude display ordered by plant heights (see Fig. 2.3); and a third is called a "stem-and-leaf plot" (shown in Fig. 2.2 and reproduced in Fig. 21.2).

Not only does graph paper (following Wertsch and Kazak, a central mediating resource in this exchange) help students say more than they know, but it also appears that adults can hear more than is said by watching what students do with paper as they speak. As shown in Fig. 22.4, RL asks students to place an arbitrary data value, and their responses show two different approaches to ordering the data collection (i.e., case magnitude displays ordered by plant names/labels or by plant heights).

If graph paper is contributing its semiotic powers in these excerpted conversations, how are these contributions consequential for where the classroom is headed? Comparing these two, local group efforts, it appears that LS and RL have their (evaluative and teaching) eyes on a different "mathematical horizon" (Ball, 1993). LS drives students towards a conventional data display (frequency histogram) that is part of their prior, shared history ("use your sense"), and she appears to orient towards this group's finished product (a frequency histogram, under her direction) as the object of instruction (Excerpt 4). In contrast, RL consistently tells students that he does not understand what they are proposing to do, but encourages them to make sure they can answer questions about typicality and spread. When he asks students to try out their display ideas with particular values (e.g., placing 121 in the, as yet, incomplete display), they disagree, and RL encourages them to work independently on their ideas (e.g., Wally pursues a stem and leaf plot on his own). In this sense, RL invites and supports variation in invented displays, which can later by compared (Excerpt 5). While James Greeno points out that RL lends authority to one student's proposal over another (i.e., Jewel's proposal to use plant names/labels is discouraged by RL and her peers), students' thinking is generally oriented towards

Fig. 22.4 RL asked students to explain their display (Excerpt 5)

conversations, later, in which different displays can be compared in terms of how well they answer questions.

It is as if RL has his "eye on the mathematical horizon" of future activity, while LS has her eye on past instructional investment. For RL, the leading question seems to be, "Where is this activity headed?" For LS, it seems to be, "Why aren't you using what you know?" Pace James Greeno's contribution to this volume, RL positions students to have (and be seen as having) conceptual agency for proposing or problematizing representational displays, while LS (at least in these local exchanges) directs students to remember and use proper disciplinary agency.

In this sense, RL's interactions with students more consistently serve a pedagogy of invention and comparison.

Looking forward in the video record (Days 27 and 28), the kind of variety that RL encouraged locally was realized in five quite different display types. Groups 2 and 3, the focal students in every target chapter, produced almost identical frequency histograms (Lehrer & Schauble, 2004, call these an "Invented display featuring intervals and relative frequency," p. 654). However, other groups produced displays showing data values as ordered lists, points in a two-dimensional coordinate system, and ordered case magnitudes (i.e., the type of display originally considered but rejected by Group 2, after RL's leading questions). All these alternatives were made available and discussed, by comparison with frequency histograms, on Days 27 and 28. This process of encouraging local variation in ideas or display strategies that can be used for comparison, later, is in my view a salient structural aspect of where this classroom is headed.

On Playful Aspects of Learning in Ensemble Performance

Clancey (Chapter 15), like Greeno, draws on Lave and Wenger's (1991) ideas about learning in social practice, but his theoretical proposals are more tightly focused on sense-making as an outcome of coordination between people, cultural artifacts, and arrangements of the physical environment. These shifting forms of coordination yield "ensemble" performances in which people, talk, and action with artifacts create the ongoing environment for each other – a transactional unit of analysis, rather than an interaction between participants and environment:

> We analyze a classroom episode as a performance by an *ensemble*, in which people are improvising, playing over and through each other. Actions are *commentaries* that promote reconceptualizing (e.g., rechunking and relating) what has transpired (i.e., what are the events of the past) and what the past means going forward. These performances are *accomplishments* with implicit structure, that constrain individual actions and that [are] sustained and developed by them. (pp. 275–276)

Following an ensemble obligates Clancey to a close analysis of what all participants to an activity are doing, together, over time. It also suggests an open stance, on the part of the analyst, to the relevance or consequentiality of actions as judged by members of the ensemble.[10] Cognition and learning, in Clancey's approach, come out of the relation between neuropsychological processes linking perception and emotion (inferred from observed behavior in the video record) and patterns of coordination between people. Ongoing coordination has a playful, reflective quality that involves multiply parallel contributions to the sequential coherence (or fragmentation) of group activity and learning. As in Lave's (1988) earlier analysis of cognition in practice, setting and person shape each other and emerge together.

Clancey's exploration of the corpus materials is, by my reading, the most comprehensive of all the target chapters. He describes a process of reviewing and making annotations over the entire corpus of video recordings, then he focuses closely on the ensemble formed by Tyler, his student peers, LS as a visiting adult researcher, and the teacher. Clancey's analysis follows Tyler's apparently disruptive contributions to early efforts at data organization (with LS; also analyzed by Wertsch and Kazak), then later his central role as a spokesperson for his group when different representations of plant data are explained and compared.

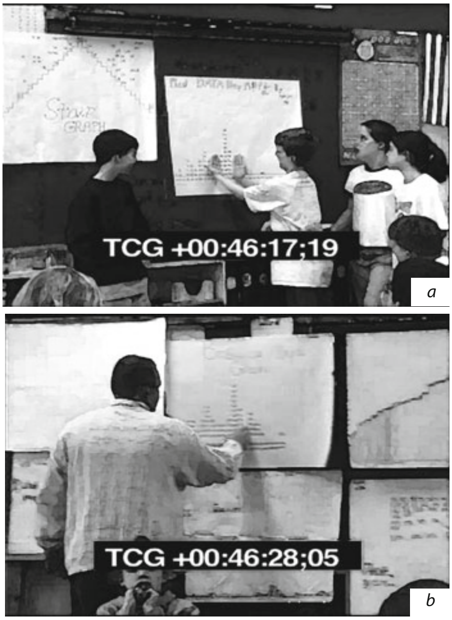
While most analyses of situated learning focus on students' learning through legitimate peripheral participation in conventional practice, Clancey's analysis of Tyler's early (Episode 4) activity documents a process of being involved, playfully, in what might be called "illegitimate central non-participation." As his group mates struggle to create a representational strategy with guidance from LS, Tyler's contributions run perpendicular to the group's apparent trajectory. However, as Clancey points out, Tyler does not leave the group, refuse to answer questions, or fundamentally dis-attend to what LS and his peers are doing. And they do not ostracize him, but play along. When this group later presents a histogram authored by other students, Tyler is positioned to act as their spokesperson, and his contribution to whole class discussion is endorsed enthusiastically by his group mates.

It is important here to be clear about the concept that this ensemble performance brings to the classroom, in addition to how students contribute to its trajectory of development. For example, several important ideas about center and spread were identified in local groups and later brought into the whole class discussion. On Day 27 (Fig. 22.5; see Excerpt 7), in a conversation with Group 3 students (Tyler and peers, the same students working with LS on Day 26), an adult researcher (CH) led them to explore the percentage of cases falling in "center" bins as a measure of whether that range of values was typical. This conversation was conducted over a frequency distribution from Group 2 (students working with RL on Day 26), in preparation for whole class discussion.

Later, during whole class presentation of displays (Excerpt 12), CH reminded Group 3 students of their idea, and Tyler explained their use of percentage in center bins to the teacher. The teacher then showed the entire class how both frequency histograms (produced and exchanged by Groups 2 and 3) supported this way of seeing center (see Fig. 22.6).

Tyler: [Around eleven out of twenty (.) plants are [(.) in this (category)
Kendall: [Well: in around that column
Edith: >I know but didn't you [say that<
CH: [Why why do you think [eleven out of
Tyler: [No we said between ((*a*))thes:e

Fig. 22.5 Students in Group 3 work with an adult researcher (CH) (Excerpt 7)



Tyler: So we thought that (1.1) out
of these three were the
((*a*))typical area?
Tyler: That's what we thought. =
MR: So that's kinda like somebody
came up here the oth- (0.8)
yesterday and circled (1.1)
I don't know who it was.

MR: April I think it was (0.4)
said the ((*b*))typical: Fast
Plant Day Nineteen was going
to be right around here. Was
that you April? [You circled
those kind of numbers that
group of numbers?
April: [Yes.

Fig. 22.6 Tyler explains how they used the percentage of cases in center bins as a good estimate of the typical plant height (Excerpt 12)

Similarly, during whole group discussion on Day 28 (Excerpt 9), the teacher asked which display would best show "the spread" if a plant height value of 555 were found (the maximum, observed value was 255). He illustrated how the 2D and line graph displays would show this extreme value (neither used a common scale, so placed 555 adjacent to 255), then a student (Kerri) noted that Group 3's frequency histogram "leaves the spaces there" when there were no observed values. Evidently seizing on this idea of "spaces," the teacher then showed how two displays using a common scale (frequency histogram and case magnitude display) would locate 555 very far from any other observed value.

Letting the timeline run over several days, Tyler's marginally illegitimate, central, non-participation is eventually transformed into delivery (on behalf of his group) of one of the jewels of the entire invention trajectory that L&S have designed: Typical plants would be found in a region that has a sizable proportion of cases near the center. This idea was originally proposed by Tyler, re-voiced and highlighted by an adult researcher (CH) working with his group, and then refined further in local conversation during Day 27 (see Fig. 22.5, this chapter, for the local invention; Fig. 22.6 shows Tyler's performance on Day 28 as a public spokesperson for the idea). As is clear from L&S's own analysis of learning in this classroom and the year before (Lehrer & Schauble, 2004; Petrosino, Lehrer, & Schauble, 2003), Tyler speaks for that obscure object of instructional desire these researchers hoped to produce: A multiplicative understanding of data distribution.

I would further argue this is the mathematical horizon that RL, in the turn sequences examined in the prior section, had his eye on during Day 26. It is the culmination of a "discussion" (Orsolini & Pontecorvo, 1992) that is designed and conducted, structurally (as a matter of participation) to invite, collect, compare, and choose among various solutions to a problem of representation (Confrey, Chapter 19, makes a similar argument).

The Discovery of Invention in Classroom Research on Learning and Teaching

There is no question that the structure of graph paper was used as a basic resource for ordering data values in this classroom. But the productive use of graph paper is a relatively small part of a broader story unfolding in a classroom already rich with a diverse collection of historical resources, directed towards comparing one type of display with another and deciding which would be most useful for answering questions about the distributional shape of aggregate data. That is, the shifts introduced by the teacher's opening task (from personal data logs, to an unordered list of collected data values, to blank graph paper) are the start of a developmental trajectory that is being carefully managed in L&S's classroom design experiment. As this trajectory goes forward, graph paper has its moments, but there is very little that graph paper can tell us about what develops over a longer timescale, or across a broader group of students and their displays.

In this sense, the powers of graph paper in Wertsch and Kazak's analysis are like weak forces, everywhere available but giving little direction to particular, meaningful human events. The affordances of graph paper make particular sense against a history of prior activity in this classroom (the rocket experiment, instruction on stem and leaf plots, students' completed plant measurements and data sheets) and the projection of future-time activity in the lesson under development (the teacher's gestured depiction of center and spread, and an expectation that local displays will circulate in public, comparative talk). Letting the story of this classroom go on a little longer (into Days 27 and 28), we find the variety of displays produced by local groups, when pitted against the virtues of a frequency histogram (Groups 2 and 3, whether "invented" by students are produced to adult specification), provides a learning environment full of (relatively) strong forces. This is the larger historical project undertaken by the L&S research team, and in which graph paper plays a necessary but not sufficient role.

By restoring parts of this larger project, I do not mean to criticize Wertsch and Kazak's development of the Vygotsky-Shpet approach so much as to extend it. Their chapter carefully explores how cultural forms shape conversations in which people learn. They use the corpus of video recordings to illustrate the Vygotsky-Shpet approach, not to explain what was happening in the corpus (broadly), the classroom from which the corpus was drawn, or to give a theory of learning that includes invention or conventionalization of cultural forms. Greeno's analysis, on the other hand, does set out to explain how learning is organized in the corpus, by comparison with two other classroom cases, around the concept of learning with conceptual agency. Students were positioned by the teacher and research team to engage with conceptual agency in generating alternative representational forms (the productive diversity reviewed above), but the activity of reconciling which among these forms was most useful was clearly organized by adults. Clancey's analysis combines nicely with Greeno's efforts by following the ensemble performance of a single group over time. Tyler's playful non-participation early in this ensemble trajectory is tolerated, and his contributions provide the raw materials for developing a proportional meaning of "center" or "typical" by the time his group takes the floor in whole class discussion. All three, target chapters help us trace how concepts are developed and sorted out over the social history of the classroom, but none of these analyses entirely grasp the broader purpose and character of the design experiment in progress within the L&S corpus. This design experiment, as I understand it, is concerned with the invention or conventionalization or representational forms.

I have come to think of this latter, theoretical project as the "discovery of invention" in classroom research on learning and teaching, and it has a history that leads directly to (and through) the L&S corpus. Encouraging local invention for later refinement into conventional cultural forms is a recent discovery by classroom researchers, and I will mention several examples that are similar to what Lehrer and Schauble (2004) describe. One of the most widely cited papers is by diSessa, Hammer, Sherin, and Kolpakowski (1991) with the striking title, "Inventing graphing: Meta-representational expertise in children." diSessa and colleagues announce,

> In November 1989, 8 sixth-grade students in a school in Oakland, California invented graphing as a means of representing motion. Now, of course, we mean that they "reinvented" graphing. In fact, we know that most of them already knew at least something about graphing. But the more we look at the data, the more we are convinced that these children did genuine and important creative work. (p. 117)

Asked to create a representation for a story about travel, students produced a variety of displays that managed time, distance, and speed in different ways (e.g., a "T" display with line segments showing speed and time), and in whole class discussion, these eventually converged on Cartesian graphing. Subsequent classroom studies found similar productive variety in students' invented representations, leading diSessa (2004) to argue,

> It is always tempting to believe only brilliant scientists create really new things, so it may not seem sensible to bring representational invention into schools. However, it is an empirical question whether representational innovation and other aspects of MRC [meta-representational competence] can profitably enter school. Our data resoundingly suggest that students can productively design new representations, even approaching standard, scientific ones. In any case, more modest goals might still be extremely valuable. (p. 296)

In a study of 2nd and 3rd grade children asked to represent a model city that was destroyed and later rebuilt, Enyedy (2005) describes processes through which "personal inventions" by individual students are appropriated by other students in whole class discussion, and through continuing debate among alternatives, eventually refined into shared representational conventions. For example, faced with the problem of drawing a "bird's eye view" of a 3D cone, one student proposed drawing progressively smaller, concentric circles, while another proposed drawing perimeter and radius (called a "cartwheel"). After further debate, orchestrated carefully by the teacher, a convention for using topographic lines (contour lines) was adopted by other students and used on subsequent mapping projects. About debate and refinement, Enyedy (2005) notes,

> the change from an invented representation to a cultural convention is not merely an objective process of selection, but also a social process of co-authorship and transformation. Given the creativity of multiple individuals, the group as a whole (if it was to act in a coordinated way) had to collectively narrow the field and appropriate only a few of the invented solutions; in doing so those solutions were elaborated and modified by the group. In this process, I again highlighted the teacher's role in orchestrating the discussions that both created the desire to have a convention and transformed multiple, personal inventions into a convention. (pp. 459–460)

Finally, Schwartz and Martin (2004) report experimental evidence that when 9th grade students are asked to invent statistical procedures before being taught conventional methods (e.g., a measure to represent variation in a sample of data values), they outperformed peers who were taught the method and asked to practice. Moreover, students in the "invention" condition were better able to take advantage of learning resources on later assessments (i.e., invention worked as "preparation for future learning," p. 168).

Across all these studies (including Lehrer & Schauble, 2004), the common discovery is that asking learners to "invent" representations or methods can lead to productive variety that is useful for comparative discussion, refinement, further learning, and development of conventional representational forms. As I think Wertsch and Kazak correctly argue, discoveries are neither expected nor (most likely) tolerated on the part of students in classrooms that are strapped for time and resources. But in the L&S classroom, students are expected and encouraged to invent, and the variation across their local inventions is an explicitly designed resource for learning and teaching. This larger activity system is missing in ways that are consequential for the target chapters, and if included, would strengthen the analysis delivered by each. Otherwise, this classroom looks like any other, and it is not, if only by force of NSF investment and the sustained presence of a substantial research staff.

Returning to the extended analogy between Partch's musical inventions and the activities contained in the L&S corpus, it may be more appropriate to pursue the analogy a level up in their classroom design experiment. If the musical score and new instruments are mapped to project-based inquiry units, then L&S are advancing our understanding of how these units can be adopted and implemented in a wider range of public school classrooms. If the musical performers for Partch's compositions are mapped to public schools (their administrators and teaching staff), the path for adoption and implementation is difficult, particularly given the deep reach of hi-stakes testing and federal accountability demands in the US context (e.g., No Child

Left Behind). Finally, if Partch's audience is mapped to parents of school-aged children and educational policy makers, they (like Partch's audience) need to learn to see this kind of teaching as leading to learning with conceptual understanding, if there is to be a demand for it. As Tyack and Tobin (1994; see also Hall & Greeno, 2008) have argued, the "grammar of schooling" is resistant to change for all these reasons, and the coherence of educational reform has usually involved exactly these challenges.

The discovery of invention may lead to changes in how we teach science and mathematics (as attested in all these studies), but it is not commonplace or conventional in public education, today. And given the polarized political climate of federal educational policy, on the one hand, and calls for an educational science that will clear the shelves of curriculum that have not been shown effective by randomized clinical trials, on the other,[11] they may not become commonplace anytime soon. Creating classrooms that resemble the remnant model offered for analysis by L&S in this volume will be a continuing struggle. Hopefully, the examples of secondary analysis collected here will provide rich resources for that common project.

> *There seem always to be enough people around to keep things moving a little, enough people with new ideas and the energy to give them a try. The problem about change is not whether there are such people but whether their ideas will be incorporated into the workings of the rest of the package, whether the changes will be institutionalized so as to get the advantage of all the apparatus that is already in place. Alternatively, can innovators create for themselves a new apparatus, which will do all those things the regular system does for older kinds of work? (Becker, pp. 306–307)*

> *Although representations are widely presented, it is far less common for instruction to maintain a consistent and explicit focus on developing students' capability and propensity to evaluate and compare the communicative value and design trade-offs of a variety of representational conventions. Nor is it standard practice for students to learn to invent new ones for novel purposes. As with variation and distribution, we consider meta-representational competence to be a general form of literacy that has very wide application and that has, in fact, played an influential role throughout the history of human thought (Lehrer & Schauble, 2004, p. 672)*

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Notes

1. The corpus of video excerpts selected for analysis in this volume comes from only three days of this larger instructional unit.
2. See Ragin and Becker (1992) for a collection of papers on how cases are made, found, or otherwise produced and interpreted in social science research. That one corpus of materials

could be used to produce multiple, divergent, but still meaningful accounts of learning and teaching is to be expected.

3. I am grateful to Frederick Erickson for an opportunity to learn more about the NHI project, through a conference he organized to celebrate the 51st anniversary of that group's work at the Center for Advanced Study in the Behavioral Sciences.
4. Video recording inevitably encodes theoretical perspectives (Hall, 2000), and this must be considered. But good quality video and audio recording are 'reality close' in a way that many investigators find more compelling than symbolic description alone (e.g., observational coding, field notes).
5. I have seen Leona go into transcription mode while in a classroom, and it is impressive. The transcripts included as Appendix B to this volume, of course, are much more accurate representations of what was actually said. Following Lehrer and Schauble (2004), I use RL for Rich Lehrer and LS for Leona Schauble.
6. Broader possibilities for learning are considered at the end of Wertsch and Kazak's paper, where they note that students in these episodes "discovered a great deal of the meaning of these cultural tools through active exploration" (p. 165). They further acknowledge that the Vygotsky-Shpet approach (a variant of cultural historical psychology) and individual constructivism might have complementary strengths.
7. Since my analysis concerns embodied action as well as talk, I use transcript conventions that are slightly different than those adopted in this volume's common transcript (Appendices A and B). These include creating "toon strips" (Hall, Wright, & Wieckert, 2007; McCloud, 1993) that index by visual juxtaposition and/or number (in single parenthesis) what people are doing with their bodies as talk is produced.
8. It is not possible to know what students noticed or understood about the teacher's gestures, but he is clearly tracing graphical shapes that are offered as reasonable answers to the questions posed by the data organization task. The semiotic ecology (Enyedy, 2005; Goodwin, 2000) in which graph paper exercises its powers includes talk and embodied mathematical activity that are available for analysis in the corpus.
9. IRE refers to a three-part, "initiation – response – evaluation" turn structure for asking "known answer" questions that is typical of didactic instruction (Mehan, 1979).
10. William Clancey frames ensemble action, as a unit of analysis, using Dewey and Bartlett, but the practical work of conducting such an analysis is equally indebted to methods of Conversation Analysis (CA). Like James Greeno, and unlike traditional studies in CA, William Clancey is explicitly concerned with the informational content of talk-in-interaction.
11. See commentaries and response on the National Mathematics Advisory Panel, in a special issue of *Educational Researcher* (2008, *37*(9)).

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Chapter 23
Reflections on Practice, Teaching/Learning, Video, and Theorizing

Frederick Erickson

Introduction

The essays in this book come from a workshop whose stated aim was "to promote reflection and discussion on foundational aspects of research on [teaching] practice." (Workshop Proposal, p. 1) The core resources provided for reflection on theories of learning are three programmatic papers—by Wertsch and Kazak, by Greeno, and by Clancey. These do not exhaust the range of learning theories that potentially could be connected to teaching practice—they are all at the end of the range that emphasizes teaching as the construction of and engagement in social interaction as a learning environment. In spite of that family resemblance in theoretical orientation each of the papers took a quite different stance in relation to learning. The main emphasis in the position paper by Wertsch and Kazak is on the construction and use of a particular kind of cultural tool—the graphic representations of frequency distribution that were developed by children in a fifth grade mathematics classroom that had been videotaped (for a description of the video materials, see the paragraph immediately following). The main emphasis in the position paper by Greeno is on relationships between interaction and learning, in particular on dynamics of argumentation among learners and on the situated identity positioning of various learners that comes through their participation in such argumentation. The main emphasis in the position paper by Clancey is a re-animation of Dewey's notion of trans-action as the social interactional ground within which human learning takes place. The book also includes sets of commentaries on the three main papers.

The core resources provided for reflection on teaching practice in relation to learning theories are a series of videotapes of fifth grade mathematics instruction that had been made by Lehrer and Schauble (see their description of the video corpus, this volume). The tapes were made on three successive days in which small

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groups of students were designing charts that would take various representational approaches in displaying frequency data on the growth of a set of plant seedlings over the course of a few weeks – the primary data were daily measurements of the height of the plants.

A further resource was commentaries on the programmatic papers and the video records by other workshop participants, including myself.

In hindsight it now seems to me that something that was not mentioned consistently in the presentations—and indeed was under-theorized in the workshop—was the nature of the interactional practice of teaching/learning itself. That "theorizing of practice" has (at least) three aspects– (1) conceptions of the real-time interactional conduct of teaching and learning (i.e. the nature of teaching and learning as social interaction and indeed, the nature of social interaction) (2) the phenomenon of the video record of that teaching and learning (i.e. how the record was made, visually and auditorially–what it displayed and failed to display concerning teaching and learning) and (3) the phenomenon of the conference participants' use of the video record in supporting the arguments they made in their papers.

As a way of addressing the theorizing of "practice," and of considering how social interaction, as a semiotic ecology constitutes a learning environment, I will begin with a short intellectual history of the study of social interaction by means of close analysis of audiovisual recordings of such interaction. That historical overview is followed by discussion of how the video excerpts that were provided were made use of by the participants in the workshop. The chapter concludes with a very brief discussion of the nature of social interaction as a learning environment and about the use of close descriptive analysis of audiovisual records of interaction as a means of studying teaching and learning.

A Review of Origins and Trajectories in the Recent Study of Interaction

It must be remembered that the so-called "cognitive revolution" and what can be called the "interaction revolution" happened very recently, and they occurred at the same time. Yet as they developed further they did not, for the most part, make direct contact with each other. As enterprises that are both only about 50 years old it is no surprise that neither enterprise has as yet fulfilled its initial promise–leaving much room for further advances in theory and in empirical work.

It seems to me that the conduct of empirical studies of learning in interaction, as that has happened within the developing "learning sciences" field, has suffered especially from the separation of the interaction revolution from the cognitive one. In my judgment many of the people who tried to study *thinking and learning in interaction* within the last academic generation didn't take as good advantage as they might have done of the development of theory and research on interaction itself. Consequently I want to present here a brief and necessarily selective intellectual history of the "interaction revolution," with some discussion of its implications for the study of learning and instruction (an earlier version of this historical overview, directed to an audience of linguists, appeared in Erickson, 2004b).

The “interaction revolution,” in which machine recordings of the continuous conduct of social interaction came to be used as a primary data source, and close descriptive analysis of interactional behavior constituted the “data” (including but not limited to the preparation of detailed transcriptions of speech) has been slightly less than 60 years in development, at the time of this writing. The very first instance of deliberate study of a machine recording of naturally occurring talk was done by the social psychologists William Soskin and Vera John in 1953 and a report of it was published 10 years later (Soskin & John, 1963). At a summer camp operated on the shore of Lake Michigan by the University of Chicago they recorded two newlyweds conversing casually. The couple was placed in a rowboat with an audio tape recorder powered by a battery that was about the size of a modern automobile battery. As the boat was being sculled forward by the wife, it was almost hit by a ferryboat that was coming in to its dock–which occasioned vehemence in the utterances that were exchanged between the two interlocutors (Vera John-Steiner, 2002, personal communication).

The first attempt to study verbal and nonverbal behavior together in talk systematically began in the spring of 1956. Gregory Bateson had used silent cinema film in the 1930s to record Balinese dancers teaching their apprentices (Bateson & Mead, 1942). He began to make sound cinema films of family psychotherapy interviews in the San Francisco Bay Area, in collaboration with Jürgen Reusch and Weldon Kees (Reusch & Kees, 1956). One of their films was made use of by an interdisciplinary study group that had been formed for that purpose during the first full year of operation of the Center for Advanced Study in the Behavioral Sciences on the Stanford University campus. The group was convened by Frieda Fromm-Reichman and Henry Brosin, who were psychiatrists. It included the linguists Norman McQuown and Charles Hockett, together with Bateson and Ray Birdwhistell who were anthropologists.

The film material chosen by the group consisted of conversation between Bateson and a mother, sitting on a couch in her living room. Her kindergarten-aged child played near them on the floor. The mother and child were also filmed as she put the child to bed. The group took an empirically conservative approach in their initial analysis of this footage. The linguists, McQuown and Hockett, prepared a continuous phonetic transcription of all the speech that occurred on the film footage. Birdwhistell prepared a continuous “kinesic” transcription of all the body motion that occurred–gesture, postural position, and gaze. (For a later version of this transcription approach, see Birdwhistell, 1970.) Bateson prepared a narrative summary of the interaction he saw taking place, and the two psychiatrists, Fromm-Reichmann and Brosin, wrote continuous commentary on what appeared to them to be clinically significant aspects of the verbal and nonverbal behavior that was taking place. One could say that this was a “Blind men and the elephant” approach, each specialist doing what he or she knew how to do. But there was a substantive point to the approach—the group did not want to privilege speech over nonverbal behavior in their analysis of communication and by preparing continuous transcription and commentary they did not select short strips of interaction for special analytic attention (having at first no clear criteria for making such a selection). By doing detailed, continuous transcription of the speech and nonverbal behavior they also were paying equal analytic attention to the listening behavior of listeners and the speech behavior of speakers. That turned out to be theoretically consequential, as will become apparent in my discussion below. Members of the group continued to meet in ensuing years, eventually producing a final report titled "The natural history of an interview" (McQuown, 1971). (This NHI manuscript was never published–its original copy now resides in the Harper Library of the University of Chicago.) Pittenger, Hockett, and Danehy (1960) published a detailed analysis of an audio recording of the first 5 min of a psychotherapy interview, indicating pauses, pitch, volume shifts, and rate of syllable production. They did not, however, have a visual record in addition to the audio record.

These initial attempts to study verbal and nonverbal aspects of interaction using machine recording as a primary data source occurred in the same years in which George Miller, Herbert A. Simon, Jerome Bruner, Harold Conklin, and others were beginning to study thinking from new points of view. After that the "cognitive revolution" got the lion's share of attention (and research funding) but an "interaction revolution" was also developing in the ensuing years. From beginnings in the NHI group an approach that came to be called "context analysis" was developed by Albert Scheflen (1973a), and Adam Kendon (Kendon 1970). In the late 1960s and early 1970s Conversation Analysis developed in sociology (see Psathas, 1995) and "interactional sociolinguistics" and "discourse analysis" developed in sociolinguistics and linguistic anthropology (see Ammon et al., 2004). In the early years of conversation analysis and discourse analysis audio recordings were used as the primary data source. In subsequent years video recordings began to be used more and more by conversation analysts and discourse analysts but they continued to focus centrally on speech phenomena in their analyses. The approach to the transcription of speech developed initially by Gail Jefferson for Conversation Analysis (see Jefferson, 2004), as a play script transcribing approach, foregrounds speech. To the extent that non-verbal behavior is represented in such transcripts it is entered in as an add-on, an accompaniment to the talk that is foregrounded in the transcript.

The "context analysis" approach is the least well known of these later streams of work but its assumptions are especially pertinent for a kind of theorizing about interaction that I want to discuss further here. The "context analysis" approach saw interaction as an ecosystem of concerted social action that was sustained across real time in the continuous verbal and nonverbal activity of all the participants in an interactional event. The "context analysis" view continued the heuristic assumption that had been taken by the NHI group that all the communicative behavior of all the parties engaged in communication was potentially meaningful. Thus there was an emphasis on the *sequential organization of interaction*–connections of meaning and of influence of various interlocutors upon one another across successive "moves" across time (e.g. speaker making a substantive point in talk, followed by listener's nodding in agreement; speaker asking a question and interlocutor uttering an answer). But there was also an emphasis on the *simultaneous organization of interaction*–connections of meaning and of influence of various interlocutors that occur at the same moment in time–the "whiles" of interaction (e.g. listener gazing and nodding toward the speaker *while* the speaker is talking, speakers and listeners simultaneously changing postural positions *while* the topic or emotional tone of talk is changing). The emphasis was on continuous mutual influence among interlocutors in the course of the conduct of interaction–the enactment of a social ecosystem in real time. In a particularly apt phrase McDermott (1976) said in his doctoral dissertation that, in our interaction, "We are environments for each other" (p. 27).

An analogous perspective was foundational in early conversation analysis, in which there was a theoretical interest in the capacities of interlocutors to organize sequences in talk, such as exchanging turns at speaking, doing this entirely by intuitive adaptive reactions to each other's actions, rather than by consciously following "rules" for turn exchange (Sacks, Schegloff, & Jefferson, 1974). Also in this same spirit of "beyond rule-following to moment by moment sense making" were the notions of "contextualization cues" and "conversational inference" developed in the "interactional sociolinguistics" of Gumperz (1982, 1992); interlocutors are able by means of implicit signals (such as voice tone, hesitation, word choice) to point to indirectly to intentions in what they are saying, usually without saying so explicitly, and they continually take account of each other's implicit hints toward interpretation as their interaction proceeds. (This sense that features of the performance of talk point beyond the talk itself to how the talk should be interpreted in the moment, and that interactional partners rely on one another's capacities to "read" such framing signals within the course of interaction is based in part on Bateson's (1956) notion of "metamessages." A family resemblance in theoretical assumptions between context analysis, conversational analysis, and discourse analysis in interactional sociolinguistics is that the orderliness that is apparent in the conduct of interaction is not a matter of deliberate rule following but of participants' intuitive capacities to use implicit means of telling each other what they are doing interactionally within the course of their doing it. This radically ecological perspective on social interaction–people in interaction as constituting environments of continuous mutual influence among one another, much of which influence is implicitly "uttered" and "read" by participants within the ongoing course of that interaction–is very different from a notion of interaction as primarily constituted by the explicit content of talk–literal meaning. The implication of this for theorizing learning practice will become apparent in subsequent discussion. An important difference among the three approaches is that context analysis, with its commitment to use of audiovisual machine recording rather than audio recording alone (which reflected its theoretical assumption that nonverbal behavior was as potentially important semiotically in the communication of meaning "gestalten" as was speech and also that the listening activity of auditors was as important to the overall semiotic and interactional ecology in face to face communication as was the speaking activity of speakers) produced a very different kind of transcribing from conversation analysis and sociolinguistic discourse analysis approaches, avoiding the "logocentrism" of the latter. (A good source of examples of context-analytical transcribing can be found in Kendon, 1990.)

Since the beginning of the "interaction revolution" in the mid 1950s and early 1960s there have been various efforts at collaborative analysis of audiovisual records of the conduct of interaction, now using the less expensive medium of video recording rather than cinema film. Albert Scheflen at the Bronx State Hospital supported work on family therapy sessions and on everyday family interaction. Among his research associates were Adam Kendon and Ray McDermott. McDermott finished his doctoral thesis, during that time, an intensive ethnographic study of a first grade classroom that also made use of Super 8 silent movie film to document teaching and learning interaction in reading groups. Hugh Mehan and his research group of graduate students at UC San Diego and I and my research group of graduate students at Harvard made the first sustained audiovisual records of social interaction in early grades school classrooms, recording half days and entire days of instruction across the course of entire school years, including video of whole class instruction and small group interaction, combining the video recording with sustained participant observation. McDermott and I were particularly influenced by the "context analysis" perspective described above as well as by the new work in sociolinguistics, and Mehan was particularly influenced by ethnomethodology and early Conversation Analysis, as well as by sociolinguistics. This work was followed soon by the video documentation and analysis of an after-school learning club by Michael Cole, Ray McDermott, and others at Rockefeller University, and by the initiation of Allen Grimshaw's Multiple Analysis Project (MAP) in which a film of an entire doctoral thesis defense was made and analyzed by a panel of invited scholars. Methodological statements of chapter length were made by McDermott, Gospodinoff, and Aron (1978) and by Erickson and Schultz (1979/1997), and a book length research report by Mehan (1979) also appeared, containing an extensive methodological appendix. At UCLA the conversation analysis group there reviewed audio and video footage in what they came to call "data sessions", brainstorming ideas for analysis. In a similar vein, from 1979 to 1985 Brigitte Jordan and I hosted an "interaction analysis lab" at Michigan State University, in which participants brought newly collected video footage for group review and analytic brainstorming by an interdisciplinary group of scholars in an eclectic approach that combined perspectives from context analysis, conversation analysis, and sociolinguistics. After 1986, Jordan then developed a similar "interaction lab" at the newly established Institute for Research on Learning (IRL) in Palo Alto, a research center which was headed by Jim Greeno, and I developed a similar interaction lab at the University of Pennsylvania and Temple University in Philadelphia, in collaboration with Adam Kendon and Anita Pomerantz. In 1995 the Jordan and Henderson manual for "interaction analysis" was published.

In sum, the overall perspective on interaction analysis whose development I have sketched above in a cursory way presumes the following things about interaction and how meaning is communicated within its ongoing conduct. First, concerning what "interaction" is not profitably conceived as—not just as talk, and not just as talk plus volume emphasis, hesitations, and gestures, and not just as organized sequentially, as in a ping-pong match—speaker A uttering something, speaker B replying in response, etc. Second, concerning what "interaction" might profitably be conceived as – as an ecosystem of mutual influence that is continuously maintained by all activity of all the participants in a given occasion of face to face contact, throughout the entire course of the conduct of that activity – and as organized both *sequentially* – involving connections of influence among participants across successive acts in time–and as organized *simultaneously* – involving connections of influence among participants at the same moment in time. From this perspective the study of interaction should not privilege talk over nonverbal behavior, nor should it privilege speaking activity over listening activity–all is of potential interest. Moreover this perspective takes full advantage, theoretically and empirically, of the fact that participants in interaction can see each other as well as hear each other–in ordinary social interaction they do not talk on the telephone or listen through a keyhole. Thus their interactional conduct is not only "embodied," as one of the current buzzwords says, but the visual availability of interactional conduct to all participants affords simultaneous monitoring by all participants of each other's verbal and nonverbal actions. Third, this perspective has implications for a theory of interactional semiosis–of how meaning is signaled and interpreted within the real time conduct of face-to-face communication (for a relatively early statement on this, see Scheflen, 1973b). Meaning in interaction involves much more than literal reference – it involves implicit metaphoric meaning. Such meanings do not just reside within single words, or within individual iconic gestures, or within single grammatical clauses, or within single verbal or nonverbal utterances, one utterance at a time. Sometimes a meaning cue may consist in a pitch level or voice quality that is sustained in talk across a number of sentences, or a number of utterances. Sometimes a meaning cue may reside in the sustained postural positions of a set of listeners to a focal speaker. The meanings are often communicated in clusters of multi-modally redundant signals–in "gestalts" made up of combinations of verbal and nonverbal behavior, as performed both by persons who are speaking in a given moment and by those who are listening in that same moment. These "meaning packages" often are communicated as allusive hints rather than as signals of specific, denotative meaning. (These characteristics of uttered meaning are variously identified as "indexicality" [Garfinkel, 1967; Silverstein, 1976; Hanks, 1992, 1996] or as "high context communication" [Hall, 1969], as "contextualization cues" [Gumperz, 1982, 1992], or as "metamessages/frames" [Bateson, 1956/1972; Goffman, 1974].) From this perspective, in direct contradiction to Saussure and Chomsky, every utterance whether verbal or nonverbal is seen as simultaneously pointing outward to the immediate situation in which it is uttered and also as pointing backward, "upstream" into the verbal and nonverbal discourse that has occurred prior to the current moment of uttering. Moreover, in addition to "on the record" uttering ("on the record" communication) during the course of interaction there is "off the record" *muttering* ("off the record," underlife communication) in "hidden transcripts" of talk, gesture, posture, and gaze (see Scott, 1990; Erickson, 2004a, pp. 144–145).

Studying Interaction as a Learning Environment, Using Video

There are significant implications of these theoretical perspectives on interaction and meaning for how we theorize and study teaching and learning, especially when we consider teaching and learning as participation in interactional communities of practice. One implication is that in interactional learning environments, "manifest" and "hidden" curriculum are always being enacted together. Thus when we see a mathematics lesson we can presume that what's going on is never just math alone. Rather what is happening is people hassling and leaning on each other in various ways, potentially "doing/being" gender, race, social class, teacher favorite, outcast, top dog, bottom dog, persuading, including, and excluding *in and through so-called "mathematics."* Moreover the people engaged in learning interaction may also be learning to do one another in – as McDermott's work has shown with excruciating clarity across the years. Classrooms are not just nice, and "subject matter" is not all that is being taught and learned. (Clancey and Greeno get at some of this in their orienting papers–Clancey in his discussion of humor and Greeno in his discussions of positionings among students.)

A consequence of all this is that in studies of teaching/learning in interaction analysts are wise not to attempt simply to look at the talk that is occurring by itself, nor only at that talk's immediately apparent literal meaning, as if such a research focus on a transcript of talk–read literally–provided an unproblematic open window into the "thought" of the speaker. Yet that is what much "learning sciences" research has done, especially that focusing on mathematics and science teaching, with funding from the National Science Foundation. Theoretically and empirically unsophisticated about interaction as multi-modal semiotic ecology, such research repeatedly drives into blind alleys, in attempts to develop theories of "learning in interaction" without adequately theorizing "interaction" itself.

Moreover, in leaving "interaction" (and/or "participation") as a residual category theoretically, the potential of continuous audiovisual records as a primary data source in empirical research is continually under-realized. Video recordings get made, but all too often they are searched for evidence in ways that are fragmentary and superficial. A principal advantage of machine recording–what makes it different from observational field notes – is that it is continuous over time in its monitoring of the interaction it is recording–although limits are imposed by when the recorder is turned on and off, while it is on it does not pick and choose what it records. This does not mean that the recording provides an absolutely unfiltered, "objective" record of the interaction that took place – and limitations of sound pickup by microphones and cutoff at the edges the visual field of a camera shot make even a continuous recording somewhat selective. But it *is* relatively unselective, nonetheless. In spite of this, novices in video analysis have a tendency to "cherry pick" moments of interest from their videotapes, failing to present a systematic rationale for their decisions about what strips within the continuous recording to focus on analytically and what strips to overlook analytically. When this kind of "cherry-picking" is guided by strong subject-matter interests, and the choices of focus are made by people who are extremely knowledgeable about subject matter and pedagogy in a given field, (as were many of the specialists in mathematics education who attended this conference) then the "cherry picking" of instances of theoretical interest can be done in a way that is ultimately effective empirically (see the discussion in Erickson, 2006). But such selectivity involves dis-attending as well as attending – overlooking as well as looking – and when the looking is not guided by a strong theory of the nature of social interaction, there is a risk of overlooking important aspects of what could have been considered analytically if better choices of analytic focus had been made.

Use of Video Examples by Participants in the Workshop

The 12 video excerpts (Appendix B) available for use by workshop participants came from footage on mathematics instruction that was provided by Lehrer and Schauble. From this corpus, chapter authors selected particular strips of footage on which to comment, and for those strips Koschmann prepared transcripts. The set of excerpts come from instructional Days 26, 27, and 28, the last 3 days in the unit of instruction that Lehrer and Schauble had developed and studied. Prior to the 3 days examined, the class had been growing Wisconsin Fast Plants® and making observations on the height of the plants. On Day 26, the teacher issued a "data representation challenge" and divided the class into teams of four (Excerpt 1). Each team designed a graph representing the data from the aggregated class measurements (Excerpt 2, 3, 4, 5, and 6). On Day 27, the teams exchanged representations and were asked to present another team's graph to the class. In Excerpt 7, one team worked to interpret a representation designed by another group. Finally, on Day 28 the teams presented the representations assigned to them (shown in Excerpts 9, 10, and 12) with interpolated commentary by the teacher to the whole class (an example of which was shown in Excerpt 11). This gives an overview of classroom scenes for the last 3 days of instruction, but not a comprehensive view of the instruction and the learning interaction that was taking place – there are many lacunae. The video excerpts for Day 26 did not show the observational notes of individual children in each group, from which the groups were deriving their frequency data displays, nor did Excerpts 2, 3, 4, or 5 show any single group's accomplishment of the complete task of inventing a representation format and entering data on it, i.e. the excerpts did not show the entire course of work by any single small group–rather across the excerpts there was a sampling from the work of some but not all of the groups. The video excerpt for Day 27 did not show the groups exchanging their graphs and working on one another's graphs. And the video excerpts for Day 28 did not show the presentations of all the groups. In consequence, the excerpts provided quite fragmentary documentation of the instruction and of the interactional processes that were occurring in the class during the culminating 3 days of the unit. From such evidence it was not possible to observe "learning" by individual children or by groups microgenetically – that would have required recording continuously one or more of the classroom groups and saving samples of their work (e.g. observational notes taken by each student in the group). And as already discussed, from this array of excerpts it was also not possible to observe the entire provision of instructional opportunity to learn – documenting the overall classroom environment's affordances for learning by students – the scatter-shot sampling of excerpts gives an observer an overall sense of those affordances – a "forest-level" sweep of the learning environment as a site of opportunity to learn – but there was not enough continuous monitoring shown in the array of excerpts to permit "tree-level" understanding of opportunity to learn.

Another limitation in what one could come to know from the video examples comes from the ways the video footage was shot. There was a good deal of zooming in on faces, from wide shot to a tight portrait shot of the speaker, often at moments when the speaker was saying something with emphasis. This is the "television talk show" way of shooting footage in a group conversation, and from the previous discussion of the "interaction revolution" it is apparent that this way of recording group conversation audiovisually is based on an implicit, folk theory of semiotics that presumes that "meaning" primarily comes out of an individual speaker's mouth, moment by moment. So that's what the camera goes for–moment by moment alternation between the heads of successive speakers. What is lost in this way of shooting is a sense of the overall social ecology of communication–notably, there is no systematic documentation of the listening reactions of listeners while the speaker is speaking. When the teacher is standing at the whiteboard instructing the class and the camera zooms in as the teacher makes an emphatic point (rather than zooming out to show the listening reactions of the students) this folk theory of the semiotics of communication as mainly consisting in "sending"–the extrusion of messages out of the mouths of individual speakers (as if the meanings came out as strips of ticker tape or as strips of toothpaste pressed from a tube) is especially apparent, and it can be seen to be driving the way the camera recording was being done. Rather than presuming that communication involves continuous processes of mutual influence among participants, the presumption in the conventional way of shooting group conversation is that Sender A produces message, Sender B produces message, Sender A produces next message, each as isolatable acts performed by individuals. When the video footage is shot on the basis of such a presumption it cannot support a systematic analysis of social participation in conversation as an ecosystem. Rather it supports an asocial, individualistically oriented analysis focusing on the content of one speaker's talk at a time.

Moreover, there was tremendous variation in the sheer length of excerpts, within the set of twelve that was made available to the conference participants (see Appendix B). The length of excerpts ranged from 49 s in the shortest clip to 18 min and 33 s in the longest. Across that range there were four modal clusters of clips, when sets are compared according to length: [Excerpt 11 (49 s) and Excerpt 2 (110 s)], [Excerpt 6 (174 s), Excerpt 10 (193 s), and Excerpt 7 (247 s)], [Excerpt 5 (315 s), Excerpt 1 (327 s), Excerpt 8 (387 s), and Excerpt 3 (464 s)] and, finally, [Excerpt 4 (694 s), Excerpt 9 (784 s), and Excerpt 12 (1113 s)]. (The transcripts in Appendix B represent the timing and performance of speech in ways derived from the transcription approach developed by Gail Jefferson, with the following exceptions: (1) the onset of every utterance or nonverbal action is time stamped, (2) certain nonverbal actions (e.g. pointing, iconic gestures, writing on the board) are included in the transcript along with the talk, and (3) pauses between turns are not indicated in parentheses, since the time stamps show the duration of each of those pauses.)

From the array of 12 excerpts the three authors of the major orienting papers, Greeno, Wertsch and Kozak, and Clancey chose brief strips of talk for comment in their papers, discussing strips from nine out of the twelve excerpts. Clancey commented on strips from within Excerpts 2, 3, 8, 9, 10, and 12. Wertsch and Kozak commented on strips from within Excerpts 1, 3, 4, and 5. Greeno commented on strips from within Excerpts 5 and 9. There was not complete overlap among these authors in the strips they chose from the array of excerpts, and no single excerpt was mentioned in common by all three authors. Wertsch and Kozak selected a strip from Excerpt 4, from which excerpt Clancey had also mentioned a strip. Wertsch and Kozak selected a strip from Excerpt 5, from which excerpt Greeno had also mentioned a strip. Clancey mentioned a strip from Excerpt 9, from which excerpt Greeno had also mentioned a strip. The comments by other chapter authors on strips of transcript taken from the excerpts also shows a pattern of absence – no systematic overlap in choices from excerpts is apparent across the various commentators. (See Table 23.1). It thus seems reasonable to conclude that the video examples and transcripts of talk that were provided did not foster coherence in discussion of theorizing learning in interaction. There were examples of interaction provided, and there was theorizing about learning presented, but no clear relationship between the two.

There are some structural reasons for the patterns of reference to examples from the video corpus that are apparent in Table 23.1, and I think there are also some more general reasons for those patterns of use. First I will comment on the structural ones. These have to do with the participants in the workshop having followed the instructions they were given by the workshop organizer. The writers of the three position papers were told to select moments from the video corpus that exemplified the theories of learning that they were developing, and they did that. Authors of the commentary chapters were to critically evaluate the theories in terms of what they made (and failed to make) visible in the videos. Most stuck closely to the excerpts selected by the respective position paper authors (exceptions are the chapters by Macbeth, Packer, Hall, Confrey, and McClain).

What might account for the decisions by the position paper authors to choose the video excerpts they did, for purposes of illustration? Clancey made the widest use of video excerpts from the Lehrer-Schauble corpus, and in discussing the video strips he also referred the most directly to aspects of non-verbal behavior as well as speech. I think this is partly because of his overall substantive concern for Dewey's conception of "transaction." That perspective is thoroughly ecological; it emphasizes organism-environment relations of mutual influence with neither the entity of "organism" or that of "environment" being assumed to be pre-existing or logically prior to the other. This leads one to emphasize the concerted, conjoint character of social interaction (very much in the spirit of the NHI group's work that led to the "context analysis" perspective I discussed earlier). Clancey also emphasized three topics – perceptual work, a playful attitude, and the purposeful context of emphasizing inherent properties of graphs. To illustrate each of these he chose multiple examples from the video footage and then discussed the examples in considerable detail.

Greeno also provided considerable illustration from video, but he did so with a somewhat more narrow substantive focus than Clancey and he also discussed video examples from his own prior work in addition to discussing examples from the Lehrer-Schauble video corpus. Greeno was concerned to show the approach he calls "situative analysis," which focuses on changes in participation by individuals – moving from more peripheral to more central participation in local practice.

Table 23.1 Overview of the video excerpts and their mention by chapter authors

Day 26 Data representation challenge						**Day 27** Groups exchange representations	**Day 28** Final day presentations discussing representations from other groups (whole class)				
Excerpt 1	**Excerpt 2**	**Excerpt 3**	**Excerpt 4**	**Excerpt 5**	**Excerpt 6**	**Excerpt 7**	**Excerpt 8**	**Excerpt 9**	**Excerpt 10**	**Excerpt 11**	**Excerpt 12**
whole class	small group	small group	small group	small group	small group	small group	whole class	whole class	whole class	whole class	whole class
Macbeth		Bredo		**Greeno** Macbeth Bredo McClain				**Greeno** Bredo McClain	McClain		
Wertsch & Kazak Packer Derry		**Wertsch & Kazak** Packer Wegerif	**Wertsch & Kazak** Packer Sherin Wegerif Derry	**Wertsch & Kazak** Packer Sherin Wegerif Derry	Packer Sherin				Sherin		Derry
	Clancey	Garrison	**Clancey**	Confrey	Confrey	Confrey	**Clancey** Säljö Cobb	**Clancey** Cobb	**Clancey**	**Clancey**	**Clancey**
Hall			Hall	Hall		Hall		Hall			Hall

Such participation manifests what Greeno calls intellective and positional identities of individual learners as they participate in disciplinary discourse, including disciplinary forms of argumentation. In his position paper he first illustrated this with video material from biology discussions in two different classrooms he had studied previously – a controversy over the proper taxonomic classification of orcas (as whales or as dolphins) and an argument about mouse population dynamics. (Having seen these video examples myself, and having participated in the analysis of the orca controversy tapes, I can attest to the richness of these two examples. I can see why Greeno wanted to mention them. Moreover, his analysis of "positioning" of various students in the arguments involves watching the video to make judgments about audience reactions as those students present different points in argumentation, although in his discussion Greeno did not emphasize this transactional co-construction as much as Clancey had done, especially as Clancey discussed the interactional co-construction of playfulness.) Greeno then turned to two examples from the Lehrer-Schauble corpus that also showed positioning in argumentation. But by then he had used up considerable airtime in his chapter. He discussed the two additional illustrations in considerable detail but did not choose other instances from the Lehrer-Schauble corpus.

The Wertsch and Kazak position paper also had a unitary substantive focus – on the students' graphing as the invention of a cultural tool. The notions of tool and invention were discussed elaborately at a theoretical level and then illustrated by one good exemplar from teacher-student conversation and by one good exemplar from student-student conversation. The focus on the graph as locally invented cultural tool did not lend itself to discussion of speaker-audience co-construction.

It seems to me that the specific reasons for the choice of video excerpts made by the authors of the three position papers had to do with the Gricean "maxim of quantity" in conversational contribution: "make your contribution as informative as required for current purposes of exchange, not more informative than is required" (see Grice, 1975). Each author had a particular substantive focus and that led to the picking of examples that illustrated the substantive points the author wanted to make in that particular position paper, saying enough by way of illustration but not saying more than was necessary.

In addition I think there are some more general reasons for the lack of overlap in choice of video examples that is apparent in the three position papers and the accompanying commentary chapters, as Table 23.1 shows us above. When we consider how much detailed information about interaction there is even in a careful transcription of speech, let alone in the full audiovisual record that allows an analyst to consider listening behavior in relation to speaking behavior, we could expect that even if analysts were presented with identical 30 s clips of video and required to comment only on those clips, they would not "see" the same phenomena in the clips. That has been my experience in showing minimally edited footage to audiences of students and scholarly peers over the last 40 years – in classes I have taught and in brainstorming video-watching seminars in the spirit of the "interaction labs" whose history I recounted earlier—we do not quickly reach high percentages of "inter-judge reliability" in what we see–rather, the contrary happens–we "see" in the tapes what our prior knowledge leads us each to see (for further discussion, see Erickson 2007, 2006).

Repeatedly people see very different things in the same strips of video footage, especially when the footage shows classroom interaction. This has also been the experience of Magdalene Lampert and Deborah Ball (1998) who by videotaping their teaching of fifth grade mathematics across the course of entire school years and saving examples of student work for each day of instruction as well as daily reflective notes written by themselves as the teacher, have created what is perhaps the most complete video archive of mathematics teaching practice (and the most complete index of such an archive). As these video records are "visited" by fellow researchers and also by student teachers there is some overlap in what different individuals notice in particular strips of tape, but there is also a good deal of variation across individuals in their noticing. Rogers Hall, in an attempt at systematic analysis of video segments from the Lampert and Ball video corpus, found that determining an appropriate analytic focus on particular strips of tape was not obvious at the outset of his inquiry (Hall & Rubin, 1998). He and I also found this as we worked from 2001 to 2006 as faculty in the consortium titled *Diversity in Mathematics Education (DiME)*, a program of instruction and fellowships for doctoral students at three universities. Our experience was that when students and faculty were asked to examine particular videotapes of mathematics instruction–portions of lessons on specific days – they were not able to agree on common patterns of noticing in the tapes as a foundation for collective analysis of the video segments. This has also been the case with the LessonLab project (Hiebert et al., 2003), which has gathered a world-wide sample of videotapes of middle grades mathematics instruction–usually as video recordings of entire mathematics lessons lasting roughly 50 min each. As visitors watch those tapes they "see" different things in them. It has been difficult to develop consensus on what is "there" to be seen. The LessonLab group has responded to this problem by developing coding schemes for categorizing various aspects of classroom interaction, and training raters to use these codes with high degrees of inter-judge reliability. A limitation in this approach–which relies on the kinds of category judgments originally developed by Bales (1950) for use by observers in real time, without a machine recording of the interaction that is being analyzed–is that in order to achieve inter-judge reliability, indexically situated local meaning is sacrificed in analyses that are based on such coded data. Using the Bales approach to coding solves the problem of disagreement among observers but it does so at the expense of nuance and interpretive subtlety.

Lack of coherence in the approaches of observers also happened in the previously mentioned MAP project that was organized by Allen Grimshaw. As various researchers looked at an hour and a half long videotape of a sociology doctoral thesis defense, they chose different strips of interaction to analyze, applying very different means of analysis to the strips they chose – and that was a set of researchers who were experts in discourse analysis and in the study of face to face interaction (see Grimshaw, Burke, & Cicourel, 1994). This was also true for the symposia published as special issues of journals, edited by Koschmann, (1999) and by Sfard and McClain (2002).

Why there is such difference in perspective when viewing what is putatively "the same" video material seems to have to do with the life experience and theoretical orientation of the perceiver. We still understand very little about the phenomenology of video viewing for purposes of systematic analysis. As we use video clips we still seem to be in the position of the three blind men with an elephant–one touches the leg and declares that the elephant is like a tree, another touches the tusk and declares that the elephant is like a spear, and one touches the tail and declares that the elephant is like a rope.

All this leads me to think that a common focus for looking at excerpts from the Lehrer and Schauble corpus would not have come from some simple expedient, such as giving all the participants in the conference the same 2 min video clip and insisting that every illustration of "learning practice" in any of the papers they produced would be taken from that single clip. And the diversity that was apparent in the ways video material was used by the primary authors and the commentators should not simply be considered as a liability, nor should the manifest naivety about interaction as an ecosystem that was apparent in the way the Lehrer and Schauble video footage was originally shot be considered as an absolute impediment to such footage's productive use in studying the teaching of mathematics, let alone in theorizing teaching/learning practice. One of the conclusions I was forced to draw, in fairness, in my recent discussion of methods of video analysis in educational research (Erickson, 2006) was that strong pedagogical knowledge and/or knowledge of subject matter content can guide researchers who, even though they may have relatively little experience in using video analytically, to do things with a corpus of video materials that enable them to construct persuasive answers to questions they have raised about teaching/learning processes. As a specialist in the study of social interaction, with little special knowledge about particular subject matters, it is a bit of an embarrassment for me to be forced to admit that.

Thus it should be said that the three primary papers in the workshop as well as the various comments on them presented much food for thought about teaching and learning, even though the "practices" of interaction by which learning is assumed to take place were left under-theorized and only very partially studied empirically. Moreover, because so many of the workshop participants understood so well the mathematics that was illustrated in the video corpus, the various participants in the workshop were able to make opportunistic use of material in the video excerpts provided by Lehrer and Schauble, and in so doing were able to advance our understanding of mathematics teaching and learning.

Conclusion

Theorizing "practice" in theorizing teaching/learning practice. There is a possibility that richer theorizing in the workshop about the nature of social interaction itself (especially about how the organization of the practices of social interaction constitutes interaction as an environment with affordances for fostering learning) combined with more empirical skill and discipline in the analysis of video materials, would have helped advance even further our understanding of mathematics teaching and learning, and would have grounded more solidly our theorizing about "practice" in teaching and learning. But the tendency to leave the real-time conduct of *interactional practice* under-theorized as a semiotic ecology, and thus to leave it un-discussed in relation to teaching and learning practice, is not simply characteristic of the particular workshop out of which this volume's chapters have come. It is a tendency I see in the learning sciences field more generally.

It is not easy to study learning, as McDermott's commentary in this volume shows us, and it is not easy to use video in the study of learning. Usually learning does not happen in discrete "Aha" moments of breakthrough to new understanding–moments that can be readily videotaped, whose analysis as an instance of learning would be straightforward. Tradition tells us that such an "aha" moment occurred for Archimedes, who in the course of taking a bath is said to have discovered displacement as an explanation for flotation. Helen Keller and her teacher Annie Sullivan both remembered and reported autobiographically Helen's childhood "aha" moment on April 5, 1887 – her sudden realization – as a girl born blind, deaf, and unable to speak–of the semiotic significance of Annie's finger spelling W-A-T-E-R as Helen's head was being splashed with water from the pump in her backyard (Keller, 1902/1961, pp. 33–35; see also the letter by Sullivan dated 4/5/1887 as printed in Keller, 1902/l961, pp. 273–274).

But in a video-based study, even if a crucial "aha" moment had occurred for an individual, if the video camera were not there to record it, such a moment would not be found in the video corpus. Most learning involves relatively continuous movement from more peripheral to more central participation in a community of practice (Lave & Wenger, 1991; Wenger, 1998) and so "microgenetic" studies of learning require repeated observation and/or audiovisual recording of the actions of individuals and groups. But if learning is indeed well conceived as increasingly complete participation in the real time conduct of the practices of a local community of practice, and if social interaction is the ecosystemic medium of local practices within which such increasingly complete participation by learners is taking place, it does stand to reason that close documentation and analytic observation of the practices that take place in social interaction holds potential for helping us get smarter about how teaching and learning take place.

More attention to the quality of video recording itself – better understanding of the differing affordances of different approaches to videotaping – can help in this. I also believe that more awareness by this generation's descendents of the "cognitive revolution" of the theoretical insights about the nature of social interaction as a semiotic ecology in real time enactment (especially as this concerns social interaction as a learning environment) that have come from what I have called here the "interaction revolution" will enable the construction of more robust theorizing about "practice," "learning," and "teaching" as the learning sciences try to understand more fully the socially situated character of learning and teaching, and in so doing come to a more powerful understanding of the social interactional circumstances within which teaching and learning tend to succeed or fail. This would be to develop a more "practice-based" theory of teaching and learning. As yet we are not very far along that road. But to continue along it seems to be a good direction in which to proceed.

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Chapter 24
Can We Afford Theories of Learning?

Ray McDermott

> Learning . . . *is fond, and proud, of what has cost it much pains; is a great lover of rules, and boaster of famed examples . . . learning inveighs against natural unstudied graces, and small harmless inaccuracies, and sets rigid bounds to the liberty . . .*
> Edward Young, *Conjectures on Original Composition* (1759)

If American culture were an Internet, the domain name "learning" would be owned outright by the testing services that use it to feed the yearnings of parents and their schoolchildren. The bell curve of learning guides and legitimizes the differential distribution of resources and opportunities across generations. From yearning to learning to earning, selection has become less about the best person for the right job, and more about the most credentialed person for the highest paying job. Given current alignments among the social classes, the institution called "learning" competes with banks, health care and pension benefits as candidate domain names for injustice. Schools and testing services claim ownership of learning in the name of the upper classes that pay tuition and tutoring fees for system deliverables one filled-in bubble at a time.

This is an unfortunate development. Learning is such a nice word. I can't go to bed until I have learned something bookish. Today's entry of useless knowledge is that Herman Melville liked to ask people walking on Gansevoort Street in Manhattan how the street got its name (Hardwick, 2000, p. 11). His pleasure – and eventually Hardwick's, then mine, and now yours – was that the street was named for his mother's family for reasons no passers-by could recall. That's cool learning: arbitrary perhaps, but fun, particularly if it is not confused with knowledge that makes a difference. It does not belong on an examination that makes a difference – what James Joyce called "our exagmination" (Beckett et al., 1929, front cover). Random knowledge should not feed the system of exaggerations that take answers to arbitrary questions as a measure of real learning.

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In a proper society, there would be little need of tests not tied directly to the performance of important tasks and no need for theories of learning to explain and modify the results. Most societies not only do without tests, they rarely develop theories of learning. It is no accident they have developed together, genuinely and/or invidiously, in capitalist democracies that promise equal opportunity and mass schooling under conditions of great inequality.[1] It is a species constant that members of *Homo sapiens* learn, but the institution Americans call learning – the institution defining learning as knowledge displayed on competitive tests set against a background of myths of inherent intelligence correlated with race and class borders – is but a century old.[2] Institutionalized learning sets the agenda, and learning theory and practice report for duty and demise.

How did exacting examinations get such sway? Note the word, exacting: literally, out of the action. How did learning get isolated and separated from conditions of possible use? Given the disconnect between school learning and the uses of learning in the world, why should we be culling theories of learning for better ways to study the practices of classroom instruction? Can we afford the word learning without retaking ownership and restoring it as a way to talk about what happens when people do something perhaps interesting enough to allow new ideas to enter the local community? While eschewing direct answers to these questions, I press political considerations for rethinking theories of learning and instruction in ways not explicitly developed in this book.

I proceed in three brief sections. The first offers an inspiration from an earlier time when William James suggested we retire another friendly word for another useful aspect of human activity, namely, consciousness. The second section compares James's effort to the three position papers that lead this volume. Together the sections target the intrapsychic control system version of cognitive theory as the demon against which the papers in this volume marshal some resistance. A third section points to specific lines of inquiry – contrary to mainstream policy assumptions – for which a restricted use of the word learning might be safe. The conclusion gives a tentative answer to the question of whether we can afford theories of learning.

Does "Learning" Exist?

> *I believe that 'consciousness,' when once it has evaporated to this state of pure diaphaneity, is on the point of disappearing all together. It is the name of a nonentity, and has no right to a place among first principles.*
>
> William James, *Essays in Radical Empiricism*

In 1904, William James wrote "Does 'consciousness' exist?" to question the analytic utility – the generalizutility – of the word, consciousness. His answer: consciousness of course exists, but not as taken. It exists not as an entity, but as a function in the organization of experience. James's answer works equally well for learning: both consciousness and learning exist, but not as things, not as substantives. It is better to build on consciousness and learning as functions in the organization and interpretation of experience. They are dimensions of sequences of activity and do not exist on their own without recursive relations to emergent and precarious environments. They are conceived, invoked, and performed in relation to multiple orders of activity and to redefine them we must examine the desires that fuel the terms and the consequences that flow from their use. James discarded consciousness "from his list of first principles," but he knew he must "still provide in some way for that function's being carried on" (1912, p. 4). For James, as for most twentieth-century philosophy: no more self-stuffed first principles.

Called into use in schools made up of individuals reduced to learning by themselves and for themselves, learning has become as misleading a term as consciousness was to James. It might be better to do without them. The goal of analysis has become not just understanding consciousness or learning, but confronting better the arrangements among the people using the terms. In an introduction to James's radical empiricism, John McDermott offered a fine line clarification:

> The dualism of thought and thing is what we do to experience, not what we find as ultimate conditions of experience. (1976, p. xxxiii)

James's message was difficult in 1904 and no less so now.[3] The simple dichotomies James and Dewey tackled still mislead. The intellectual gymnastics around thought/thing, subjective/objective, organism/environment, and individual/social have all moved and morphed into the central divisions discussed in this book: cognition/engagement and individual learning/social participation.

The way of speaking that says learning, like consciousness, exists in the head, as a thing, is mostly a bad way of speaking. A better way of speaking would tackle how learning functions in the organization of activities across persons in transit, across emerging environments, and over time. A better way of speaking would take into account how learning and doing have been pulled asunder into separate phenomena. Ray McDermott on learning restates John McDermott by changing only two (underlined) words:

> The dualism of learning and doing is what we do to experience, not what we find as ultimate conditions of experience.

To clean house in psychology in 1904, James had to attack consciousness. To clean house in education in 2010, we have to attack the mainstream version of learning as isolated, measured, supported by a century of experimental findings, and institutionalized for public consumption. Because we are guardians of children, institutionalized attention to learning is more than in our way.

Yes, Learning Exists, But It Is Difficult to Talk About How It Works

> *Certain it is that words, as a tartar bow, do shoot back upon the understanding of the wisest, and mightily entangle and pervert the judgment.*
>
> Francis Bacon, *The Advancement of Learning* (1623)

James set a prescient standard for bracketing the troublesome substantive entities that have dominated twentieth-century educational psychology: skill, ability, identity, competence, self, decision-making, strategic maximizing, reflex answering, and self-esteem hoarding all as characteristics of stand-alone, stand-still persons – neither in the world, nor of the world, and ex-actly so. These are distinctions people do to each other and not primal conditions of existence. Run of the mill–good for the till–psychology and education have institutionalized them into realities. Like James, the main authors in this book are trying to translate learning from a language of autonomous entities to a language covering activities, particularly discourse, with locatable consequences. Greeno, Wertsch and Kazak, and Clancey move learning into the world–Greeno into social interaction, Wertsch and Kazak into mediating devices, and Clancey into organism/environment transactions–although it always struggles to return, as if from a tarter bow, back into the head.[4]

James Greeno is a complete study on the play of thought and things in contemporary learning theory. He has been an innovator for 50 years. Trained as a behaviorist, he turned in the 1960s to cognitive research (Greeno, 1980). In the 1980s, he added thicker environments to the experiments he found good to think with and the wider world to which he was, with the help of interviews, expanding his results (Greeno, 1995). In the 1990s, he shifted focus to social interaction in classrooms (Greeno, et al., 1999). We can trust him to write with honesty and wisdom about where he has been and where he is going. He always makes progress and progressive progress.

Greeno's paper uses classroom data to study the mutual consequences of "cognition and learning in interaction" – not cognition and learning in interaction with each other, but cognition and learning both in social interaction. His agenda requires both a psychology and a sociology of living organisms interacting in real time–in simultaneous retrospect and prospect.[5] His psychology employs an interactional language of persons thinking in activities concerted with emergent environments, but his social vocabulary invites a more substantive image of identities in fixed positions. Like James a century before, Greeno can win his argument, but lose to the compulsions of language that make consciousness, learning, identities, roles, statuses, and positions into things.

Greeno conveniently reduces his argument to a chart.[6] His first column views facts about learners through a cognitive psychological lens, for example: "performing procedures, search[ing] in problem spaces, . . emergent understanding, . . expanding effort toward accomplishing goals . . . [and] conceptual growth." These are organized from bottom to top according to increasing layers of thought and reflection, with "performing procedures" at the bottom and "persistence in learning practices" at the top. The terms cover increasing connections with complex activities, from routinized responses on the bottom, to well staged, multilayered, planned lives at the top.

The second column shows an equivalent list of terms developed by a situated perspective in the explanation and enhancement of cognitive practices, from "mutual attention . . . [and] conceptual common ground" on the bottom, to "change of discourse practice, . . . [and] positional identities in school with mutual engagement and productive agency in relation to a community's joint enterprise of learning" on the top. The second column offers a productive summary of concerns for anyone

Table 24.1 Greeno's levels of analysis of cognition in activity (simplified)

Achievements to be explained	Situative analysis
(4) Conceptual growth, commitment to learning goals, persistence in learning practices	• Changes in discourse practice • Intellective identities regarding learning, academic learning, and learning specific subjects; positional identity in school and classrooms with engagement
(3) Expending effort toward accomplishing goals	• Practices of problematizing, reconciling, and positioning students in disciplinary discourse with competence, authority, and accountability
(2) Emergent understanding	• Negotiating different interpretations or mutual understanding • Problematizing, reconciling, and positioning in interaction
(1) Routine comprehension, conceptual understanding, and problem solving	• Conversational contributions to mutual attention and understanding of propositions and reference • Conceptual common ground and shared repertoire of schemata and procedure

worrying about more ecologically tuned ways of approaching cognition. As Macbeth says, the chart "is done very well" (endnote 3, p. 100). The chart nicely reverses the preoccupation of mainstream psychology on the lone organism – the eunuch of analysis – and establishes instead a focus on the activities of persons dealing with the pushes and pulls of the social world.

William James would have been proud that the situative column gives simultaneous agency[7] to participants and their environments, but it can also be read more mundanely (as by Collins). In the bottom box, "shared," "common," and "mutual" are key terms that focus on behavior between persons in on-going concerted activities. Analytically, this is exactly what is needed – or its opposite. Sharing, holding in common, and mutuality can undermine the case if they postulate two independent centers that engage and share.[8] Seeing learning and development as an acquisition of traits and competencies leaves mainstream educational and psychological thought undisturbed. Seeing learning and development as an acquisition of persons by contexts reflexively organized for differential displays of skill across a social order is one radical alternative. Greeno recommends the second, but carries enough of the first to call for their marriage. This delicate balance requires an interactive language that can inhibit a return to the head as the executive site of learning. Macbeth summarizes:

> On this account, interaction is the constitutive field of the cognitive discourse, and though Greeno says further that his project "aspires to a theory that is primarily about interaction in activity systems," I think he subsequently thinks better of it. In the end, the appropriation seems to work from the other side: Concepts are appropriated from the situated perspective and rendered as aspects of interpersonal systemics and informational semantics. (p. 79)

The term cognition carries centripetal power. Even as the dependent variable, cognition can bring phenomena back inside the head; instead of being accounted for, it can do the explaining. In his thoughtful response, Greeno acknowledges the tension between a situative approach transforming cognitive theory (his want and wont) and a situative approach dragging along a cognitive theory that ultimately consumes the social (wanton words, like a tartar bow). He suggests the tension is productive if it allows analysts to turn in and turn out and to be explicit about their analytic bets. While turning in, Greeno's learners are still cognitive. They problematize, negotiate, solve and resolve problems, take on identified positions and positioned identities, and gather up their self-esteem, and then the afterthought analyst gets to how the participants have had to borrow, beg, and steal their busy cognitive lives from others. While turning out, no one gets to negotiate or resolve on their own grounds, and the analyst has to with a description of the environments participants use to negotiate and resolve things together. The in-and-out tension leaves a potential analytic power but, if read incorrectly, a political danger: that social interaction gets treated as only a context (the con surrounding the text) for what really counts institutionally, namely, individual behavior leading to individual learning. Turned-inside decision-makers and command center learners, negotiators, identity-grabbers, and explainers do well in the market. Cognition sells, but can we afford it?

Wertsch and Kazak move learning from inside the head to heads and hands engaging the world, but with more attention to the hands – to the literal handling of thought and thing. Drawing on Vygotskian tradition, they have less to recover from than Greeno. They are not dogged by the conceptual excesses of twentieth-century American psychology: from an early half-century of mindless behaviorism to the later half-century of overly mindful no-action subjects of cognitive psychology (see Bredo, 2006, for a relevant history). Wertsch and Kazak focus on persons using the tools available to solve problems the world has delivered. Like James, Husserl, and Marx before him, Vygotsky resisted easy dichotomies that could erase analytic efforts to make sense of human ingenuity. He wisely critiqued the seemingly neutral spaces between dichotomies:

> [any] attempt to occupy a middle ground between two extreme perspectives . . . fails to gain a position above the other two and assumes a position between them. To the extent that it overcomes the extremes of one perspective, it assumes the extremes of the other. It rises above the first false theory by yielding to some extent to a second which is equally false. It overcomes the extremes of the second by yielding to the first. (1934/1987, p. 197; for fun with false forced choices, see McDermott & McDermott, 2010)

Can we stop analytic terms from attacking themselves in an endless cycle of paradoxical moves, like Bateson's (1972) double-binds, by which either side picked is less for not being the other side, and the excluded middle – neither side A, nor side B – eats away at whichever side grabs attention. Greeno's solution, remember, is to engage the tension and to keep track of it. Wertsch and Kazak instead try to by-pass the problem by locating the materials–both rubber and road–in which thought and thing engage each other.

Following Vygotsky, Wertsch and Kazak take the world to be a system of signs with persons and things as mediating devices within the organization of signs. With all the things one could have examined in a classroom mathematics lesson, they focus on the graph paper the teacher distributed for modeling–and muddling–data. They offer little justification for their choice,[9] but it works nicely for their point. The graph paper is suggestive enough that, as the children muddle along with helpful questions from playful (withholding) adults, their ideas take on the shape of graphs. We can always do more with others than by ourselves, said Ralph Waldo Emerson,[10] and we can do more with graph paper than without. Language, math, Wikipedia, etc., are roads in the transportation system making, serving, and constraining minds in action.

So where is the learning? Not just in the head, not just in social interaction, not just on the graph paper, but in all these as they have been constructed in a social history. Vygotsky is famous for stressing the primacy of the social world in a child's learning, but he also talked about its gradual internalization. Hood, McDermott, & Cole (1980) suggested that internalization is overrated and that mental functions starting in social relations should be treated analytically as if they stayed in social relations:

> People learn about themselves and about each other by the work they do constructing environments for acting in the world. And this is how we must come to know them as well. (p. 158)

Wertsch and Kazak return to the mind through mediating devices, but there is a price to pay. In exchange for analytic clarity, it becomes difficult to talk about teaching and development as anything more than manipulating an environment. Imagine the exhortations: Teachers of the world, uhhm, mediate well:

> Given that the goal is to socialize students to use socioculturally provided and sanctioned semiotic means, the issue is how to engage them in a way that will lead to increasing levels of expertise. (p. 164)

It is difficult to imagine William James getting excited by the instructional practice brought forward by Wertsch and Kazak's bland advice. It almost invites a return to an institutionalized pure cognition complete with its dual (and dueling) social function: the documentation of those who know more and those who know less on tests. Two points for anyone knowing about the street named for Melville's mother. Remember that James gave up on consciousness because it estranged people from the flow of experience. A focus on mediation delivers more environment perhaps, but not much sensuousness or experience worth having.[11] We can afford this version of learning, but don't expect a rush of buyers.

If Greeno had to dance carefully to keep his analysis from focusing solely on what people know, Wertsch and Kazak have had to remove the people from their analysis.[12] If Greeno tries to out-maneuver the tartar bow of cognition, Wertsch and Kazak leave the arrows in the quiver. What hard work for all of them. What kind of society makes it so difficult to talk about what children and teachers can do together? The social functions of school credentials and measured learning won't go away. When it comes to learning theory, what shouldn't sell – namely, isolated heads filling up with knowledge and intelligence just in case they might be useful someday – sells all too well. What should sell–people engaged with each other and emergent environments in productive social settings–doesn't sell at all. Learning theories deserve a better political environment in which to work. So do their children.

The balance point between thought and thing becomes more volatile with Clancey's focus on "the biological aspect of cognition." Fifty years ago, neuropsychologists (Lashley, Luria, Pribram) were ahead of mainstream experimental psychology in articulating an activity theory of thinking and learning, but the present function of MRI-driven brain talk (in no way Clancey's fault) puts the world completely inside the individual head. If the tartar bow of cognition can draw Greeno and even Vygotsky (if not Wertsch and Kazak) into an executive head, imagine what it can do to a neuropsychological inquiry. Clancey's difficult balance pits the transactional language of Dewey and Bentley (1949; see Garrison's commentary) against an executive brain. The vast vacuum between them is left unobscured by his analysis of classroom interaction. For units, Clancey appeals to (sub)consciousness, intentions, norms, single speakers with consequences before next speakers respond, and assumptions about what each participant knows and feels. Here is his interpretation of laughter following a mistake:

> The reaction is quick and subconscious. Overall this laughter suggests a good rapport between the teacher and the class, and affirms a norm for handling slips, which are unintentional mistakes in someone presumed to know better. (p. 261)

This discourse analysis relies on reading each utterance/mutterance without recourse to either retrospect or prospect. It relies on an omniscient native hearer interpreting each person's talk – one speaker at a time – without a transactional, or even interactional, account of what speakers and hearers might be doing together.[13] A transactional position is difficult to state, and a transactional analysis is difficult to sustain. Both tasks pale before the task of getting mainstream educational and psychological researchers to understand. Can Clancey afford a theory of learning under such conditions?

Special Circumstances for Focusing on Learning

A century of learning theory can still be used to positive social purpose. Much of it can be used to celebrate the learning people do in the world while mastering languages, sports, trades, difficult situations, and nuanced performances of all kinds. There is no activity without learning. One needs the first half of a sentence to know how to say the second. Learning is ubiquitous to any sequencing of behavior. This position is better than its seeming opposite–that learning does not exist–but I am willing to entertain each one depending on the circumstances to be confronted and reorganized. Deciding for or against a theory of learning is a political act.

Some settings seem well organized for theories of learning to grow without risk of heightening social inequalities. The most important thing about them is that they keep no norm-referenced records – no file cabinets filled with names attached to numbers consequential to gaining admission to next institutions of high, higher, and highest learning. These settings claim less about changing the whole world than

I would like, but, given the present situation of education in the American political economy, they allow a rediscovery that children are always learning complex things and that theories of learning, when not restricted to the concerns and measures of school, can offer insight and encouragement to those who would like to learn. Learning has been so invidiously incorporated into social structure that a mere existence proof, the mere display that those said not to be learning are constantly learning, becomes difficult and rewarding work. Even if school systems have disconnected learning and teaching from situations in which knowledge might be useful, settings can be organized where learning and inquiry can join together without forcing concerns about misappropriation and mystification. The promise best covers small educational programs: individual classrooms with great teachers, alternative schools, and, most popularly, after-school programs (Cole & The Distributed Literacy Consortium, 2006; Hedegaard & Chaiklin, 2005). This is also true – in less controlled, but collectively more invigorating ways – of the digital worlds popular among children of all ages. After a century of theories about how hard it is to learn to read, a new generation of phone-messaging teenagers have invented new literacies without a theory of differential learning in sight. If we can save the word learning for events like these, we might have something to work with and work for.

A Tentative Conclusion

Oh, dear! What have I talked myself into now? Should we really question the utility of a favorite word? No way I am giving up the fun of learning about the Melville family's street, but I am willing to relinquish its claims to status. Democracy and education are under duress, and learning has been getting deployed under invidious conditions.

Can we afford theories of learning to help us organize more school success and less failure? The answer: Not under present conditions. Since the end of WWII, children and teachers have been abused by theories of learning designed primarily to document what they do not or cannot do. Researchers, in turn, have tried to theorize ways to make things better without considering either why they have been invited (even paid) to do so or how institutional conditions might twist their theories into new versions of established hierarchies.

Do we need the papers in this book to squeeze best new versions of learning theory from videotapes of experimental classrooms at work? Of course we do, but not without confronting political circumstances. Joining theory and practice in a school system that pits all children against all children and allows success only in relation to the failure of others is a cruel joke. Under better circumstances, teachers would know what to do, and so too would parents, and so too researchers, at least sometimes, and maybe even policymakers. The problem facing teachers is not that they do not know what to do, but that they are asked to do so in a system that requires every child to do better than every other child. The problem facing researchers is not that they do not know how to tweak the system creatively, but that they must do so in classrooms where teachers have to commandeer more success for some and less for others. Under better circumstances, parents and community workers would also know better, and policymakers would superfluous.

If theories of learning feed fictions to the convenience of those who have what they need, then we must take a stand. If theories of learning feed factions and are enforced by those with access to resources against those without access, then we must take our stand forcefully. The stand: analytically and social structurally, learning does not exist, at least not as theorized in America education. The common sense assumption that learning exists as a thing, inside the head, and available for display on tests, comes with a downside: that we get the schools we already have, with the price that we fail the masses and recreate students as badly divided in school as the rich and poor are divided outside school–and with the same individuals at the bottom and top. Inside this functional order, it might be better to say: learning does not exist.

This position is rhetorical and political. If taken seriously, it confronts injustices allowed by three easy and nasty American assumptions: that people with education know more, as different from only knowing more of this, but not that; that intelligence accounts for differential success, as if regardless of differential opportunities; and that social structure is a worthy measure of how things inherently have to be rather than a measure of access to power.

Without a theory of differential learning, complaints will be loud. What then of schools, know-how, credentials, licenses, expertise, mastery, genius? Can we find more democratic ways to talk about such things? No one wants to give up getting serviced by whatever wisdom is available. It's all we have. With governments claiming knowledge not from science, but from inspiration, conviction, and the invisible hand of god and/or market, we need to treasure whatever learning we can get our hands on. Note the phrasing. *Getting our hands on learning* is more than getting learning into our heads. *Getting our hands on learning* means getting knowledge close to the action, in the fabric of life, well-distributed, and literally at hand. Without learning as the stuff of privilege, we must still produce the best knowledge: that which best serves the people. Inquiry must start with the people. Dewey (1927) stated the goal:

> A more intelligent state of social affairs, one more informed with knowledge, more directed by intelligence, would not improve original endowments one whit, but it would raise the level which the intelligence of all operates. (p. 210)

Learning, the one we want to talk about, the one we want to exist–as much of it as possible–is best understood not in terms of what one person or another knows, but in terms of what is collectively known, who has access to it, and what is being done with it. In the twentieth-century, most disciplinary psychology has serviced an oligarchy, and it has become difficult to restate Dewey without sounding foolishly romantic and/or unduly radical. Psychometrics–notice the term psychometric: literally, crazy rulers–have become the Joe McCarthy of learning; they measure pink on the faces of kids at the top of the class the way McCarthy measured pink in the politics of their grandparents. The papers in this volume challenge 50 years of oligapsychology in the name of learning for all. They insist that the best pedagogy has to serve community more than isolated students, and they allow the hope that good research can alter the politics of researchers as much as the situation of those being researched. It shouldn't have to be this hard, but it is. New learning theories must confront current injustices more directly.

Notes

1. A millennium of Chinese civil exams developed according to criteria quite different, but no less strange, than our own (Elman, 2000).
2. Anthropologists working in traditional societies rarely had to study learning as an institution separate from other activities. Consider the fine account from Africa by Meyer Fortes:

   > If children are allowed to be present at the activities of adults, they are assumed to be interested in and to understand what is being said and done . . .with ordinary skills and interests of daily life, they expect children to want to know such things. . .'Heaven teaches them,' they say, or as we should put it, it is perfectly natural. (1938, p. 37; see Lave & Wenger, 1992)

3. James (1911) claimed 20 years of doubt about the usefulness of the term consciousness, and Dewey (1940) identified three stages: from James's essay on stream of consciousness in 1884, through *The Principles of Psychology* in 1890, to "Does 'consciousness' exist?" in 1904. As for learning, James (1899) mentions the term only 10 times in *Talks to Teachers*, mostly to refer to memorizing. Dewey uses it only 800 times across his 37 volumes: about 400 in passing and many more modified – "rote," "mere," and "school" learning – to contrast with "growth." Dewey defines learning mostly as what happens while people are doing something else:

   > Learning is the product of the exercise of powers needed to meet the demands of the activity in operation. . .a necessary accompaniment, the more so as being largely the unconscious effect of other acts and experiences. (Dewey, 1937, p. 238)

   James and Dewey care about how people coordinate heads, hands, and hearts to engage environments creatively, not about what goes into their heads.
4. The reappropriation says less perhaps about the authors than about how they are interpreted by the people building and profiting from American education. In contrasting the authors, I have worried more about addressing public issues and abuses than the nuanced arguments of their papers.
5. Although they are now associated with ethnomethodology, James used these terms in a 1904 essay: ". . . we live prospectively as well as retrospectively" (1911, p. 42).
6. Greeno's original chart (Table 3.1) has three columns, one each for learning achievements, the psychological processes behind them, and a translation into interactive terms. For ease of discussion (and with his permission), I present only a simplified version of his first and third column.
7. Agency: not another word for individuals, but for persons actively, artfully, and reflexively involved in making the environments that invite their next moves.
8. See Garfinkel's (1967) devastating critique of sharing as an analytic term in the study of social behavior.
9. Compare, for example, Goodwin's (1994) high energy analytic moves around the same medium.
10. Emerson: "this thrill of awe with which we watch the performance of genius, [is] a sign of our own readiness to exert the like power . . . we are entitled to powers far transcending any that we possess" (1894, p. 49).

11. In Wertsch and Kazak's defense, other people's classroom videos are a hard place to find life.
12. Because even Vygotskian learning can be melted into cognition, Wertsch and Kazak might be right. Witness the reduction of zones of proximal development into a word for teachers scaffolding ignorant students to new knowledge. A better formulation would focus on environments – from graph paper to the Internet – that would allow children and teachers to rearrange their mixed skills into momentary competencies.
13. For more transactional analyses, see Erickson's commentary, Schegloff (1988) on Goffman's miscourse analysis, Sacks (1974) on laughter, and Klemp et al. (2008) on mistakes.

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Appendix A: Transcription Conventions

Speech timing		
Timed silence	(1.8)	Represents intervals of silence occurring within (i.e., pauses) and between (i.e., gaps or lapses) turns at talk. (Measured to a tenth of a second)
Micropause	(.)	A timed pause of less than 0.2 s
Brackets	[ ]	Marks the beginning (and sometimes end) of speech produced in overlap by two or more speakers. When two or more speakers begin in overlap, double brackets are used
Equal sign	=	Marks two sequential "latched" fragments of talk that occur without intervening pause
Other prosodic features		
Period	No.	Indicates a falling pitch or intonational contour at the conclusion of a turn constructional unit (TCU)
Question mark	No?	Rising vocal pitch or intonational contour at the conclusion of a TCU
Exclamation point	No!	Marks the conclusion of a TCU delivered emphatically
Comma	no,	Indicates a continuing intonation with slight upward contour, as in the enunciation of an item in a not yet completed list
Hyphen	yup-	An abrupt (glottal) halt at the conclusion of a syllable
Sustained enunciation	no:	A sustained enunciation of a syllable vowel, or consonant is transcribed using one or more colons
Pace	> < < >	Portions of an utterance delivered at a noticeably quicker (> <) or slower (< >) pace than surrounding talk
Volume	°no ° NO	Degree symbols mark speech produced softly or at a lower volume than surrounding talk. Capitalization represents speech delivered more loudly than surrounding talk

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Stress	*yes*	Underscoring indicates stress on a word, syllable or sound
Pitch	↑ no	Arrows mark a rise (↑) or fall (↓) in intonation
Special symbols	#, $	Talk delivered in "creaky" or "smiley" voice is enclosed in pound or dollar signs, respectively. Speech delivered as if quoted is enclosed in quotation marks
Breath sounds	Hhh •hh	Audible sounds made either by expelling the breath (e.g., laughter, sighing) or sharp inhalation are presented as a series of "H"s (with a preceding dot for inhalation). When breath sound occurs within a word, it is set off with parentheses

Additional transcript notation

Parentheses	( )	Speech transcribed with some uncertainty
Double parentheses	(( ))	Annotation (in italics) describing action or providing other commentary

Appendix B: Excerpts from the Classroom

Excerpt 1: Day 26 (0:00:07–0:05:34)

```
0:00:07 teacher:  And what we want you to do: is (0.4) we're
                  going to give you a piece sheet of graph paper
                  (0.8) and I want (0.5) you to organize the
                  data (0.3) some way. (1.5) Ahm:: (1.1) and
                  eventually what we're going to do with that
                  data is we're going to have you: (0.6) ahm::
                  the kind of thing before with rockets (0.9)
                  ahm: (0.9) and I know Rich you had a question,
0:00:28 RL:       Ahm (how spread out are the) fast plants, at
                  day nineteen.
0:00:31 teacher:  ⌈⌈So the two questions that we'll eventually be
                  answering are (.) once you get your data
                  organized
0:00:31 teacher:  ⌊⌊((turns to write on board))
0:00:40 teacher:  ⌈⌈Are one, umm
0:00:40 teacher:  ⌊⌊((writes "1."))
0:00:44 RL:       ⌈⌈What's the typical height °is that°?
0:00:44 teacher:  ⌊⌊((writes "What is"))
0:00:46 teacher:  Izz yup (0.5) ⌈and we put them all into what
                  did you guys do your measurements in?
0:00:47 teacher:                ⌊((turns away from board to face
                  class))
0:00:53 teacher:  What unit?
0:00:55 teacher:  April?
0:00:54 April:    Centimeters.
0:00:56 teacher:  Centimeters. We just convert em' in because we
                  had like nine point four an' (.) we converted
                  them into millimeters so we could get rid of
                  the decimal points.
0:01:03 teacher:  So those are all of your measurements in
                  millimeters (.) so they may they may look a
                  little different to you up there but (0.9) if
                  we were to put the decimal point in it that
                  may be Tyler's.
```

0:01:14	teacher:	Ahm (1.2) okay so what is (3.0) ((*writing "the height"*)) the height of the typical (1.2) ((*erases*)) of the typical height (1.5) and who remembers the second question?
0:01:29	teacher:	((*completes writing "typ. height?"*))
0:01:39	teacher:	Cindy, do you remember what the second question was?
0:01:45	Cindy:	What's the the width?
0:01:47	teacher:	No: it wasn't the width.
0:01:52	Cindy:	How ⌈spread out
0:01:52	teacher:	⌊Ian?
0:01:53	teacher:	Yeah! Go again say it again.
0:01:54	Cindy:	How spread out?
0:01:55	teacher:	Yeah, how spread out so (.) do they all fall at the exact same point or does it seem like there's a range the plants can fall in.=How spread out are they?
0:02:04	teacher:	((*writes "2. How spread"*))
0:02:10	teacher:	And if you could answer these questions by the end of today, you've done pretty well.
0:02:14	teacher:	((*completes writing "out are the heights?"*))
0:02:18	teacher:	Say Jewel you had a question.
0:02:21	Jewel:	Well (.) I was wondering there is more than twen-ee (0.8) five (0.8) numbers there's like
0:02:29	teacher:	Yeah, there's uh sixty (.) three numbers you um some of you had three plants in a pot?
0:02:34	Jewel:	Oh yeah.
0:02:35	teacher:	And we we took remember the F six and what we were calling high light which was (.) just the same as regular light so (.) we've combined all those.
0:02:43	teacher:	So does that make sense to you now?
0:02:44	Jewel:	Yeah (kay).
0:02:45	teacher:	Debbie?
0:02:46	Debbie:	I don't get it at the top it says F six and then day an then nineteen an then (1.0) data an then=
0:02:53	teacher:	=So this is F six (.) ⌈and it's al:so:: (1.0) high: lights:
0:02:53	student:	⌊( ) F six since day nineteen
0:02:60	teacher:	So thez are tha two- those- those are tha two experiments tha we combined cause there's rilly no different- uh- bu' you agree that there's no difference between those two? If they'r under tha same light (.) an we put six pieces of fertilizer in each one.
0:03:09	Debbie:	Uhm hmm.
0:03:11	teacher:	So those are tha two experiments tha we're looking at, an its on day: (.) nineteen.
0:03:15		(1.4)

0:03:16	Debbie:	So: ( ) tha- tha numbers under dday are rilly (.) from F6 an high lighting? (1.0) Cuz there's- numbers under day.
0:03:24	teacher:	*((underlines the text at top of data list on flipchart))*
0:03:27	teacher:	Ths- these aren't tha col- >are you thinkin these are column headings?<
0:03:30	Debbie:	Yeah.
0:03:31	teacher:	They're not column headings. >Ths is<- F6 (.) an: high: lights: (1.0) frum day ninetee:n.
0:03:37	Debbie:	Oh:, uhkay.
0:03:39	teacher:	Ah:, an thRL:- th- th- th- its all: in millimeters.
0:03:42:	Debbie:	Yup.
0:03:45	teacher:	Ya understan- ya understan what yer lookin' at now?
0:03:47	Debbie:	Yeah.
0:03:47	teacher:	Yeah.
0:03:48	teacher:	Yeah I can see ⌈how you can look and say oh yeah
0:03:49	teacher:	⌊((*gesturing toward the columns on the flipchart with pen in right hand*))
0:03:51	teacher:	But they don't doesn't go that way. ⌈This is just like a title.
0:03:53	teacher:	⌊((*pointing with pen toward the table title*))
0:03:55	teacher:	Janet?
0:03:55	Janet:	Well okay, I don't get it. Are we not showing tha:: width? is are those width or height?
0:04:01	teacher:	Good question that's those are all the heights (0.4) that you you guys already measured (0.7) we just took them (0.5) here's all we did
0:04:08	teacher:	((*walking to desk and lifting up one of the student data sheets*))
0:04:11	teacher:	The data came from the sheets that you guys turned into to me on Friday, what I looked is I found anything that was: (0.8) ⌈high light, (0.8) or F-six (0.6) and you have and I wrote down Day Nineteen and the numbers that you had.
0:04:08	teacher:	⌊((*pointing toward data sheet held in his left hand*))
0:04:23	(Janet):	°Okay.°
0:04:27	teacher:	Other questions?
0:04:32	teacher:	Okay so (0.3) ↑once again in your group what are you going to be doing?
0:04:40	teacher:	Is your hand up Tyler? or not.
0:04:43	Tyler:	Ahm workin' on those questions.
0:04:46	Tyler:	⌈⌈Find out the answers.
0:04:46	teacher:	⌊⌊Okay.

0:04:47 teacher: You're gonna ⌈(.) first
0:04:47 Tyler: ⌊first
0:04:48 teacher: First you're gonna organize your data
0:04:50 Tyler: Yeah and then we're gonna
0:04:51 teacher: And then we'll probably ⌈discuss how we're going to do this::
0:04:53 teacher: ⌊((*pointing with piece of chalk in left hand toward the two questions written on the board*))
0:04:54 teacher: Ahm: and so you can be thinkin' about that as you as you're starting to organize your data, (1.0) ahm:: (0.4) well we'll discuss how to answer these questions. How we might go about that.
0:05:08 teacher: Okay.
0:05:10 teacher: ⌈⌈Rene want to pass those out? one to each group.
0:05:10 teacher: ⌊⌊((*lifting a stack of sheets of graph paper from desk*))
0:05:14 teacher: This your final copy (.) sheets that you will be putting up in front of everyone so:
0:05:34 teacher: Here's your final copy, here's your pen for your final copy.

Excerpt 2: Day 26 (0:08:08–0:09:58)

0:08:08 Caleb: Okay,
0:08:09 RL: And you decide ⌈what it is (0.6) you want to do.
0:08:09 Caleb: ⌊so >>this is what it is<< in order from lea:st to greatest like Kent said.
0:08:12 Kent: Yeah but its thirty (.) well from where? say from zero:? or starting from the least?
0:08:17 Caleb: Star- starting from the ⌈least height. =
0:08:18 Caleb: ⌊((*does a double point toward Kent*))
0:08:18 Garrett: = to the greatest.
0:08:19 Caleb: From like if it's fifty then the nex- one at seventy.
0:08:23 Kent: So::: would you start at z:⌈ero:?
0:08:25 RL: ⌊Can you tell me what ⌈you guys (0.4) zero: or the least? =
0:08:26 Caleb: ⌊No! you start
0:08:28 RL: = I wasn't sure I understood ⌈what you meant.
0:08:29 Caleb: ⌊The least is ⌈what
0:08:30 Kent: ⌊What I'm sayin' is what (0.6) okay if you started at the least like at fifty-five (0.5) then:: then it'd be all screwed up becuz
0:08:37 Garrett: The least is (forty-six)

0:08:39 Kent: ⌈Right.
0:08:39 Kent: ⌊((*turns body toward flip chart at front of room*))
0:08:39 Garrett: ⌊((*orients head in direction of Kent's line of gaze*))
0:08:40 Garrett: ↑Yeah ⌈right, (   )
0:08:41 Garrett: ⌊((*raises right arm and points toward flip chart*))
0:08:43 Caleb: Yeah right ⌈there.
0:08:44 Caleb: ⌊((*raises arm and points with left hand*))
0:08:48 Caleb: Sure? did you look through all of them?
0:08:49 Garrett: °Um hm.°
0:08:51 (Caleb): Alright (   ).
0:08:52 Kent: Okay. (0.6) Okay (0.5) it starts with zero
0:08:55 Garrett: Um hm.
0:08:55 Kent: And then we could probably go up to thirty.
0:08:57 Garrett: I'm, agree:ing with you. (0.3) Start at zero (0.5) cuz you don't start at thirty.
0:09:02 Kent: Yeah. That'd be all screwed up.
0:09:05 Caleb: Okay.
0:09:05 RL: Well can you tell me why you're worried about where you start it? What do you mean?
0:09:09 Kent: Well becuz- ahm: you start at thir:ty, (1.0) and then if you >jus like< (1.0) then: (1.3) >it's gonna< (0.8) it's just all kind of weird starting from (.) ⌈↑thirty
0:09:20 Garrett: ⌊Plants wouldn't ⌈start from (   )
0:09:21 Caleb: ⌊Yah, don't you start from lowest height (.) to the highest height that it has on the sheet.
0:09:26 RL: Oh lowest to highest. Well that seems like a different idea than starting at zero.
0:09:30 Caleb: Cuz if we start at zero then it's just like "Oop we have one number here". and we jus (.) do we start at zero and then we say "thirty"?
0:09:36 Kent: Yeah but (.) do plants start out at thirty? Or at zero:? =
0:09:39 Garrett: = ⌈⌈Well we're not really talking about plants.
0:09:39 RL: = ⌊⌊Well what (0.4) ⌈what day is it?
0:09:41 Caleb: ⌊They start off at
0:09:42 Kent: Nineteen.
0:09:42 RL: What day are we talking about?
0:09:44 Caleb: Nineteen.
0:09:45 Kent: OH::: so we would start at thirty.
0:09:47 Caleb: Yes cuz (.) it doesn't make any sense to start at zero number when ⌈they're not even up there.
0:09:51 Kent: ⌊Oh yeah!
0:09:52 Kent: Oh, okay.

0:09:53 Caleb: Yeah we should start at (none).
0:09:55 Kent: But where should we ⌈s:tar::t?
0:09:57 Caleb: ⌊( ) would be a
start. =
0:09:58 Kent: = What's your nex::t? six:ty-three squares
like this,

Excerpt 3: Day 26 (0:11:10–0:18:54)

0:11:10 April: >We can do it on this side< (.) too.
0:11:11 Anneke: Wait ⌈but what way are we doing this?
0:11:12 Wally: ⌊YOU CAN DO IT on any
si⌈de that you ⌈want=
0:11:13 April: ⌊I know ⌊I know
0:11:14 Wally: =But I think it should be on this side (.)
because then we have mor:e room: to do the
data and we still ⌈have (room)=
0:11:20 Anneke: ⌊>No we don't.<
0:11:20 Anneke: =We even ( )! No! No!
0:11:23 April: Oh my gosh you guys! You're (.) you're arg
arguing between doing this side or this side?
0:11:27 Anneke: Guys wait, >no wait a minute.<
0:11:28 Wally: This side or this side. ⌈>This side or this
side.<
0:11:29 Anneke: ⌊Wait!
0:11:29 Jewel: NO! No. But are you saying the bottom would
be here and the top the highest? (0.3) of
⌈the numbers right there?
0:11:35 Anneke: ⌊>WAIT A MINUTE! WAIT A MINUTE!< (0.5) How-
⌈>okay.< >how many numbers are up there?< how
many numbers are (.) up there?=
0:11:35 Wally: ⌊↑Ten: (.) twenty thirty forty >fifty sixty<
0:11:39 Anneke: =How many numbers are (.) up there?
0:11:40 Jewel: Sixty ⌈(something).
0:11:41 (April): ⌊Sixty-three.
0:11:41 Anneke: .h⌈h >Okay.< Could you put sixty-three:
things across here?
0:11:41 Wally: ⌊Eighty eighty
0:11:44 Wally: No.
0:11:45 (April): Yes!
0:11:46 (Jewel): May:⌈be!
0:11:46 (Wally): ⌊NO.
0:11:47 Jewel: It would do that!
0:11:48 Anneke: YOU CAN'T DO ⌈IT
0:11:49 Jewel: ⌊Five ten >fifteen twenty twenty-
five thirty thirty-five forty forty-five fifty
fifty-five sixty sixty-five seventy seventy-
five eighty (eight-five)
0:11:56 Wally: JEWEL.
0:11:56 (0.6)

0:11:57 Wally: Look at this=

0:11:57 Anneke: =Do it this way.=

0:11:58 Wally: =TEN TWENTY THIRTY look ten twenty thirty forty fifty sixty seventy eighty ninety one hundred and that's not even half.

0:12:06 Anneke: Yah. >Just do it this way.<

0:12:08 Anneke: Come here across here. We'll count.=

0:12:10 Anneke: =>>I(hh) don't wan(hh)ta count.<<

0:12:11 Wally: This way?

0:12:12 Anneke: Yah.

0:12:12 Wally: One two three four five six seven eight nine ten twelve thirteen fourteen fifteen six(.hh)teen seventeen eighteen nineteen twenty twenty-one >(   ) ⌈(   ) twenty-six twenty-seven twenty-eight twenty-nine thirty thirty-one thirty-two.

0:12:21 Jewel: ⌊I know that's what I'm saying!

0:12:26 Anneke: Okay >>times that by two.<<

0:12:28 Anneke: That's like six=

0:12:28 Jewel: =Thirty-two, sixty-four

0:12:30 Anneke: Yeah >sixty-four.<

0:12:31 Jewel: Rig(hh)t(hh)!

0:12:32 Jewel: I don't wan- I think the numbers like the like the the DOT would be like right here but it sez ⌈like (   )

0:12:37 April: ⌊OKAY you guys? We're gonna hafta do across and down anyway.

0:12:41 Jewel: I know I jus- (.) ⌈num::bers right her::e and then

0:12:42 April: ⌊I think just draw that first.

0:12:45 Wally: Yah. We we should do it like this jus draw a across and draw a line ⌈up

0:12:50 April: ⌊>I think we should do<

0:12:51 Wally: Then we can do it (0.3) anyway.

0:12:54 April: Just draw it firs:t.

0:12:55 Jewel: (   ) *((singing))*

0:12:59 (Anneke): Get another ruler.

0:13:00 Wally: You're singing right now?

0:13:02 Anneke: Huh heh heh.

0:13:04 Jewel: So sad.

0:13:05 *((April writing numbers from the flip chart across the room))*

0:13:07 April: Oh da:mn! I wrote the wrong number and I can't find where I am

0:13:10 Wally: Oh::: ⌈poor

0:13:11 Anneke: ⌊How many nu- no count how many you have.

0:13:13 April: Six.

0:13:14 ((*Anneke goes to flip chart*))

0:13:15	April:	No I (got it).
0:13:17	Wally:	She has: it Anneke,
0:13:18	April:	I have it I have it.
0:13:22	Jewel:	I'm a bad eraser.
0:13:23	April:	Look okay.
0:13:25	April:	One one oh three.
0:13:26	April:	>One oh three.<
0:13:26	April:	Look at >>look at the number one three one oh three.<<
0:13:31	April:	That's where I am.
0:13:32	April:	Yeah.
0:13:33	Anneke:	Alright.
0:13:34	April:	It's::
0:13:38	April:	Yeah.
0:13:40	April:	>What's the number after that?<
0:13:40	Anneke:	One fifty five.
0:13:48	Wally:	And don't go all the way!
0:13:50	Wally:	( ) information on it upwards.
0:13:56	April:	(It'd) be six two.
0:14:00	Wally:	Could you agree with us yet?
0:14:02	Jewel:	°No.° And I don't really get what you're fighting about.
0:14:06	April:	Okay, what way do we want to do it?
0:14:08	Wally:	This::.
0:14:09	Anneke:	Jewel, you can't do it this way.
0:14:11	Jewel:	>What?<
0:14:11	Anneke:	>Don't do it this way< cuz then >>you can have more room to write it.<<
0:14:15	Anneke:	>Wait ⌈we're not doing it that way.<
0:14:16	April:	⌊She's doing it that way.=
0:14:16	Jewel:	>What, Ap(hh)ril?<
0:14:18	April:	She's trying to line that that way.=
0:14:20	Anneke:	°Oh:: yeah:⌈::!°
0:14:21	Wally:	⌊>Oh, you know what I think we should do?< I think we should put it up this way.
0:14:24	Anneke:	Why:?
0:14:25	April:	Why not that way?
0:14:26	Anneke:	>Yah?<
0:14:26	Wally:	Cuz usually the Y-ax-axis is on the lef:t.
0:14:30	April:	That's true.
0:14:31	Anneke:	Does it?
0:14:31	April:	Yeah.
0:14:32	Anneke:	>Wait-wait- STOP STOP STOP stop stop<
0:14:33	Jewel:	No::::?
0:14:34	Anneke:	It's on the left.
0:14:35	Jewel:	Which is the left?
0:14:37	Jewel:	This is the top, this is the bottom what dya' mean the left? The left would be (.) over here.

0:14:42 Anneke: The left would be right here. No right here.
0:14:43 Jewel: No it woul⌈dn't
0:14:43 April: ⌊Okay you guys, we wanna do this.
0:14:45 Jewel: You're looking at it from this (0.3) point of view, okay?
0:14:48 Anneke: No we aren't! We're ⌈doing it this way.
0:14:49 April: ⌊Yeah, we're (looking at it) this way.
0:14:50 Jewel: What::?
0:14:51 Anneke: JEW⌈EL!
0:14:51 Wally: ⌊(Look up here) Jewel.
0:14:51 Wally: Jew:el we're doin' it from thi:s ⌈point of view.
0:14:54 Anneke: ⌊This is the bottom, this is the bottom.
0:14:56 Wally: Bot::tom:::.=
0:14:57 Jewel: =That doesn't work!
0:14:58 Wally: Up:::?
0:14:58 Anneke: Do(hh)es!
0:14:59 Wally: Bot::⌈tom:::. Up up up.
0:15:00 Jewel: ⌊Can you make two hundred some right here?
0:15:02 Anneke: Two hundred fifty some?
0:15:04 Anneke: Yeah. Two hundred ⌈some.
0:15:05 Jewel: ⌊No this is
0:15:06 April: There are sixty-three:.
0:15:08 Anneke: This is sixty-three and then you have all the numbers goin' up this way.
0:15:11 Wally: >Ya do< ⌈ten twenty thirty forty fifty=
0:15:12 Jewel: ⌊BUT ANNEKE!
0:15:15 Wally: =⌈sixty seventy eighty ninety and so on.
0:15:15 (Anneke): ⌊sixty seventy eighty ninety one hundred
0:15:18 April: That a hun:dred and that's that's like half way so we could do fives. Two hundred. (0.7) We can do fives.
0:15:23 Jewel: We can do ⌈tens.
0:15:24 Wally: ⌊( ) go up to two hundred ( )
0:15:26 Jewel: YES IT DOES it goes above two hundred and twelve.
Jewel: No (.) wait
0:15:31 April: No, hundred ten, two hundred thirty, two hundred fifty (up to here). Okay you guys?
0:15:44 Jewel: That's doing it in tens.
0:15:45 April: So?
0:15:46 Wally: So it (.) IT WILL BE A LOT EASIER it will be a lot easier than having it all ⌈screw:y over here
0:15:51 Jewel: ⌊But that doesn't make sense there's mo:re right there than right here.
0:15:55 Anneke: If it's (longer) you want to use it ⌈right there.
0:15:56 Jewel: ⌊NO.

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0:15:57 (Anneke):  No you do:n't.
0:15:58 Jewel:     ↑Yes I do::.
0:15:58 (Anneke):  ↑What's a matter?
0:15:59 April:     So you're going to put sixty-three (.)
                   sixty-three numbers acrost here?
0:16:02 Jewel:     YAH.
0:16:03 Jewel:     Are you saying that you are going to put two
                   hundred some numbers across here?
0:16:05 April:     ⌈⌈YES:.
0:16:05 Anneke;    ⌊⌊Yeah.
0:16:06 Wally:     No:. We're gonna we're gonna put (.)
                   twenty-fiv:e numbers across there.
0:16:11 Wally:     (BECUZ) they're all going up in tens.
0:16:14 Jewel:     What?=
0:16:14 Anneke:    Wait ⌈(.) ten, twenty, thirty, forty, fifty,
                   sixty, seventy, eighty, ninety, one hundred,=
0:16:15 April:          ⌊Yah::↓.
0:16:20 Anneke:    =⌈one hundred ten, twenty, thirty, forty,
                   fifty, sixty, seventy, eighty, ninety one
                   hundred =
0:16:20 Jewel:     =⌊But you don't have to do it that way you can
                   go five (    ) twenty twenty five thirty thirty
                   five forty >forty five fifty<.
0:16:22 Anneke:    =one hundred ten twenty thirty forty fifty one
                   hundred sixty one hundred seventy one hundred
                   eighty hundurd ninety two hundred
                   ⌈(      ) five
0:16:26 Jewel:     ⌊It's mor:e accur:ate.
0:16:28 April:     So how many
0:16:29 Wally:     (Too       ) five ten fifteen twenty twenty-
                   five thirty, thirty-five forty, (.) forty-five
                   fifty, fifty-five sixty, sixty-five seventy,
                   seventy-five eighty, eighty-five ninty, ninty-
                   five one hundred and that's more than half.
0:16:41 Jewel:     Fine than you can do it or you can
                   (                              )=
0:16:45 Anneke:    =Take a vote take a vote
0:16:46 Anneke:    Alright who's ⌈(                 )
0:16:47 Jewel:                   ⌊O::h I don't un:derstand your
                   wa::y!
0:16:50 Anneke:    >Alright alright< here's we have all the
                   >sixty-(three)< ⌈numbers
0:16:52 Wally:                     ⌊Okay >>wait wait wait wait<<
                   take everything off off the table so we can
                   turn it so Jewel's looking at it
0:16:57 Anneke:    NO! stop
0:16:57 Jewel:     Wait s⌈top
0:16:58 Anneke:          ⌊STOP
0:16:58 April:     Stop!
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0:16:58 Jewel: (Let me make) sense are you going to go (0.3) are you gonna go one fifty-nine (.) one sixty-five (.)⌈one sixteen?
0:17:02 Anneke: ⌊Yes.
0:17:04 Anneke: Yes.
0:17:04 Jewel: But that doesn’t make sense.
0:17:05 Anneke: Yes it does!
0:17:06 April: We’re S:::t we’re looking from Wally’s point of view ⌈now
0:17:08 Anneke: ⌊Yah:.
0:17:08 Anneke: You two switch places switch places.
0:17:10 Wally: Jewel Jewel come over here you see how they ar:e this is the X axis
0:17:15 Anneke: Yes.
0:17:17 Anneke: And this where we have all: these ⌈(different) numbers.
0:17:18 April: ⌊We could do it either way okay you guys? But how are we gonna fit fit the numbers we’re gonna haf to do three: numbers in each square.
0:17:26 Anneke: It’s just be easier to do that
0:17:28 April: We’re gonna haf to do that
0:17:30 Anneke: And then do all the other numbers this way
0:17:31 Jewel: Okay. Are you saying (.) one fifteen comes (somewhere about) here ⌈so you’ll write one fifteen right here?
0:17:35 Anneke: ⌊Yah.
0:17:37 Anneke: No this is where we put one fifteen.
0:17:38 Wally: Wait a second you guys (0.6) day nine teen (.) Eff six and um (.) whatever
0:17:47 Jewel: That’s what I was saying, so why does it matter?
0:17:50 Jewel: (I was asking ⌈about) putting sixty-three numbers on here.
0:17:51 April: ⌊What do you mean?
0:17:53 Jewel: Just put day ninetee:n (.) and then you have the numbers right here and then you put the Xs:.
0:17:58 Wally: Day nineteen and ( )
0:18:01 Jewel: You don’t haf to put all any numbers.
0:18:03 (Anneke): No I thought it’s (.) I thought we had three number? going (this way)=
0:18:07 Wally: =Okay Anneke, Anneke, Anneke Okay. Fifty-three numbers? Okay. that would be telling them with the graph. That’s why were making the graph.
0:18:15 Jewel: We’re saying it’s Day Nineteen what (.) how is it going?
0:18:19 Anneke: ↑I see::.
0:18:20 April: Yah but you haf to label it.

0:18:22	Jewel:	I know it's called Eff six ⌈day nineteen data Eff six ( ).
0:18:24	Wally:	⌊day nineteen data Eff six ( ).
0:18:27	Anneke:	>WAIT a minute< (0.7) (then the)
0:18:30	April:	Oh:::::!
0:18:31	Wally:	Okay finally! Hh huh.
0:18:33	April:	Well you could you didn't you didn't you weren't trying to make that point Jewel.
0:18:20	Jewel:	Yes I was:.
0:18:39	Wally:	No::: you weren't.
0:18:40	Jewel:	Yes I was.
0:18:41	(Jewel):	No:::::.
0:18:42	Wally:	Sixty-three numbers across there.
0:18:44	Jewel:	Okay poop.
0:18:44	April:	>Where's my pencil?<
0:18:47	Jewel:	I don't have it.
0:18:49	(April):	>It's right there.<
0:18:50	Wally:	I've got the pen::::.
0:18:53	Anneke:	So wait a minute. How are we doing our graph now?

Excerpt 4: Day 26 (0:20:51–0:32:25)

0:20:51	LS:	So it looks like (.) the numbers will go from thirty↓ to two fifty-five?
0:20:54	Edith:	Yeah.
0:20:55	LS:	Think about arranging them on this chart. What makes them the same?
0:20:57	Edith:	What's (0.6) um::: (.) from um
0:21:00	Jasmine:	Like from one to (nuthin') heh heh from one to the biggest?
0:21:02	LS:	You can't go all:: (.) you can't use all of those numbers >(and) fit on here< so: how do you want to divide them up?
0:21:09	Jasmine:	*((sneezes))* sorry.
0:21:10	(Kendall):	Ahh:::
0:21:11	LS:	Thirty, can I write on your sheet?
0:21:13	LS:	Thirty is the lowest number and you want to go: oh god I can't write upside down very easy >can I?<
0:21:17	Jasmine:	Hah he.
0:21:18	LS:	Hm:::.=
0:21:18	Edith:	=You can write upside-down ⌈we'll (.) figure it out.
0:21:20	LS:	⌊Help me out ⌈Okay yah. Two fifty five ⌈come on (don't make me do it).
0:21:20	LS:	⌊*((gestures toward Jasmine to finish recording on sheet))*
0:21:21	Jasmine:	⌊Huh hhuh two fifty: hehh five the(hhh)re↑

0:21:24 LS: Okay. So:: if we wanted to show: numbers from thirty to two fifty five on this page what would (we) be thinkin' about?

0:21:32 (Tyler): Ah:::

0:21:33 Edith: We could write ⌈s::

0:21:34 Tyler: ⌊Whoops!

0:21:34 Edith: What?

0:21:35 Tyler: ↑↑Whoa ah::↓↓

0:21:36 LS: Tyler's still working on putting them in order.

0:21:39 Tyler: I messed up

0:21:39 Kendall: What number are you on?

0:21:41 Tyler: One:: sixty-six.

0:21:42 LS: How many numbers do we have to cover from thirty to two fifty-five

0:21:45 Jasmine: Lots.

0:21:46 Tyler: ↑↑Ou ah::↓↓

0:21:47 LS: Exactly?

0:21:49 Jasmine: Sixty three tha- that are on that (.) she:et over there.

0:21:52 LS: Wha- what was our ra:nge of the valu:es there? You know sixty-three numbers but they go some thirty to two sixty-five so ⌈how how much do they span?

0:21:58 Tyler: ⌊Make that one twenty-three,

0:22:00 Jasmine: ↓Two twenty-fi:ve↑

0:22:02 LS: Two two twenty-five?

0:22:03 Edith: Wh::at?

0:22:05 Jasmine: Yeah.

0:22:05 LS: So somehow we gotta show two hundred twenty-five numbers on a pa⌈per that has:: (0.5) many ⌈( ) square that probably should be on a square.

0:22:08 Tyler: ⌊Twenty-six,

0:22:09 Tyler: ⌊We've got (.0) twenty-five, =

0:22:11 Kendall: = No, twenty-four.

0:22:13 Jasmine: KENDALL you're crink-ling: the paper. Get out!

0:22:15 Kendall: Are you sure?

0:22:16 LS: Alright ⌈can I slip the paper out from underneath here, uh: just here?

0:22:17 Tyler: ⌊We don't (.) care.

0:22:17 Jasmine: You do too::.

0:22:20 LS: Let's see how many numb- how many squares we have (>just for the heck of it<) (0.4) ⌈one ⌈two three four five six seven eight nine ten=

0:22:23 LS: ⌊((*pointing with her pen, begins counting off squares across the top edge of the graph paper starting in the upper right-hand corner*))

0:22:23 Jasmine: ⌊two three four five six seven eight nine ten =

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0:22:27 LS:        = ⌈⌈eleven twelve thirteen fourteen fifteen =
0:22:27 Jasmine:   = ⌊⌊eleven twelve thirteen fourteen
0:22:29 LS:        = ⌈⌈sixteen seventeen eighteen nineteen =
0:22:29 Kendal:    = ⌊⌊one seventy-six, you have three, four
0:22:31 LS:        = twenty twenty-one twenty-two twenty-three
                   twenty-four twenty-five twenty-six twenty-
                   three twenty-four twenty-five twenty-six
                   twenty-seven ⌈twenty-eight twenty-nine =
0:22:34 Edith:                  ⌊twenty-eight
0:22:34 LS:        = about say about thir:ty squares.
0:22:36 Edith:     Thirty-one- thirty-two squares.
0:22:37 Tyler:     Thirty ⌈times one two three four five
0:22:37 Tyler:            ⌊((using the eraser end of his pencil
                   as a pointer, begins counting down the right
                   edge of the paper starting in the upper,
                   right-hand corner))
0:22:38 LS:               ⌊Okay (1.3) and we have how many (.)
                   ⌈(did you say six) hundred and twenty-five
0:22:42 Jasmine:   ⌊((starts counting parallel to Tyler, but on
                   the opposite end of the paper))
0:22:51 Tyler:     There's twenty-six.
0:22:52 Jasmine:   Okay, thank you.
0:22:53 LS:        Twenty-six?
0:22:54 LS:        'Kay:.
0:22:57 LS:        So it looks it looks like we better save our
                   longest (0.6) si::de (0.6) for that (1.0) two
                   hundred twenty-five value
0:23:06 Tyler:     ↑↑What? ((with gaze directed toward something
                   Kendall is writing on paper))
0:23:08 LS:        Whatcha doin' here Edith?
0:23:09 Jasmine:   It's Jasmine.
0:23:13 LS:        You seem to be doin' somekinda (.) math
0:23:13 Jasmine:   Yeah I'm just seeing how many squares we have.
0:23:17 Jasmine:   We have eight hundred ninety-six- I think I
                   got that wrong (             )
0:23:21 LS:        (First off) tell me what you're doing.
0:23:24 Jasmine:   I'm do:ing ⌈(.) thirty-two
0:23:25 Edith:                ⌊She's doing thirty-two: times
                   twenty-six
0:23:27 Jasmine:   Which is the length and the width so,
0:23:29 LS:        Oh. Well we don't want to know how many
                   squares we have altogether right? Say we-
0:23:32 Edith:     We know we have more than enough.
0:23:35 LS:        Well if you're going to put a number in every
                   single square is that the best way to show it?
0:23:39 Jasmine:   We can probably fit a number in like three
                   squares. So you divide this whole number by
                   three. (.) And then you
0:23:45 LS:        Well now wait a minute let's stop a minute and
                   think about what is it that we want to show.
                   We know we have these numbers, we know they go
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from thirty to two hundred and twenty five, what would be a good way of showing our data so that we can look at it and say oh I kinda have a sense

0:23:59 Jasmine: Well we could=

0:23:59 LS: =of the different sizes of fast plants.

0:24:01 Jasmine: We can like um add these together because you know >one two three four five< we could jam together you know? And then we could use just the even numbers or the odd numbers cuz one is an odd number and then we could just show the odd numbers maybe

0:24:14 LS: Well what if we had (.) a col:umn, (0.5) sa::y (0.5) >let me think about this for a ⌈minute< (.) two hund'rd- (.) you have two hundred and two- (and) thirty, two hundred twenty-five num::bers↑ >two fifty<

0:24:18 Edith: ⌊((*Rolls her eyes*))

0:24:24 LS: What if we did something and we had one square and we said lets put all the ones in there that go from this to this (.) and then every number (.) that was in that value we'd put a little X (0.5) you know like the frequency (charts) we did?

0:24:35 Edith: O::h↑!

0:24:38 LS: So you could make kind of (0.8) a way of (.) ⌈seeing more X's when there are mor:e

0:24:41 Jasmine: ⌊hhe he he

0:24:44 LS: I'm not making myself very clear, am I?

0:24:45 Jasmine: Hha ha I don't know what you're talking about actually.

0:24:48 Edith: But we could, we:=

0:24:49 LS: Do you get a sense of what I'm talking about, Jasmine?

0:24:50 Edith: Yeah but

0:24:51 Jasmine: That's Edith.

0:24:52 LS: That's Edith ⌈and you're Jasmine?

0:24:53 Tyler: ⌊Say it again (.) maybe ⌈they'll follow

0:24:54 Edith: ⌊Hehehe

0:24:54 Jasmine: ⌊Hehehe

0:24:55 Tyler: Cuz you know they don't listen. So (.) >say it again.<

0:24:58 LS: Well I wasn't very clear (.) I was thinkin' (.) we certainly don't have two hundred and twenty five numbers across here (.) but if we said let's use a square and put all the ones that go from say thirty tah:: to fifty or sixty and then: every time we see a number we could put an X above it?

0:25:17 LS: You understand what I'm saying?
0:25:18 Edith: Yah-
0:25:19 LS: It would give a line of Xs for all: the numbers between thirty and sixty
0:25:24 Edith: ⌈and then could like (.) °for°
0:25:24 LS: ⌊And then we'd have another square between sixty and ninety=
0:25:28 Edith: =and then we could do ninety blahblah
0:25:30 LS: Or maybe we could do it with twenties I don't know lets count, twenty forty sixty eighty one (.) ten- twenty forty sixty eighty. That would be (.) maybe we could even do it by tens↑.
0:25:40 (Tyler): ⌈(Yeah↑) probably.
0:25:40 LS: ⌊Ten twenty thirty forty fifty sixty seventy eighty ninety one twenty thirty forty fifty sixty eighty ninety on:e. (.) Ten twenty thirty forty ⌈fifty sixty seventy eighty ninety two ten twenty thirty forty fifty
0:25:46 Edith: ⌊Fifty sixty seventy eighty ninety one
0:25:51 LS: If we did it every ten (.) every group of ten we have plenty of room on the pa:per.
0:25:55 Edith: Okay. We could- yeah we could do that. ⌈Yeah that's (.) that's a good idea.
0:25:58 LS: ⌊Well that's one way of doing it but I don't know if it makes sense to you guys?
0:26:01 Edith: It makes sense to me:.
0:26:02 Tyler: Oh I get it!
0:26:04 Tyler: So yeah yeah what so
0:26:07 ((*Theatrically collapses on table*))
0:26:10 Jasmine: •hhh hahaha
0:26:11 Kendall: TYLER, okay we have ten:
0:26:13 Tyler: Like so the ones like (.) you said- you write one through ten?
0:26:18 LS: Yeah ⌈( ) like that.
0:26:18 Tyler: ⌊Like all the ones one through ten you put Xs for?
0:26:20 LS: Well what we have to do is everybody (has to) look carefully through their list (0.5) your ordered list that you made and um:: (1.1) first you guys: may start or you girls may start and you make ( ). How many do we have (0.5) from: thirty to forty? The boys have none, but I think the girls have one or two.
0:26:36 Jasmine: We have like ⌈one
0:26:37 Tyler: ⌊Yeah have thirty
0:26:39 Jasmine: ⌈⌈We have one
0:26:39 Edith: ⌊⌊Two::::,
0:26:40 LS: You ⌈have one?
0:26:40 Edith: ⌊No.

0:26:40	Jasmine:	>We have one.<
0:26:41	LS:	So we would put one X above that square. Then we would say how many do we have from forty to fifty?
0:26:47	LS:	An you guys have any from forty to fifty?
0:26:48	Jasmine:	We have like two ⌈we have two.
0:26:49	Edith:	⌊We have ahm:: one fifty and
0:26:52	Jasmine:	We have forty-five.
0:26:53	Edith:	Oh:::! ⌈.hhh oh yeah
0:26:54	Jasmine:	⌊We have forty five and (point seven).
0:26:56	LS:	So you put one X and then another X. You know what I'm saying?
0:27:00	Edith:	Yeah.
0:27:00	LS:	Or maybe you could even write the actual sco:res in the squares so you could go back later and check to see that you have them all.
0:27:06	Edith:	Okay.
0:27:07	LS:	You understand what I'm sayin'?
0:27:08	Jasmine:	>Yeah.<
0:27:09	Edith:	Okay.
0:27:10	Jasmine:	We didn't really have (forty) seven right?
0:27:12	Kendall:	No.=
0:27:12	Edith:	Do we have forty two?
0:27:14	Jasmine:	No we don't have (a forty).
0:27:15	Edith:	We have a one forty↑.
0:27:18	Jasmine:	Okay so,
0:27:19	Kendall:	Don't write anything yet.
0:27:20	Jasmine:	hhhshhh
0:27:21	Jasmine:	Ahm:: pencil. Thank you.
0:27:23	Jasmine:	Hehe⌈hehehehe
0:27:23	Kendall:	⌊Right now we have to write numbers one and (0.6) right now we have to write which um our lowest numbers are? Highest numbers.
0:27:31	Tyler:	Thir:ty is the lowest,
0:27:32	Edith:	It's not going to be as hard because=
0:27:34	Tyler:	=⌈⌈Our highest is two fifty-five.
0:27:34	Jasmine:	=⌊⌊Because we have these already done.
0:27:36	Tyler:	Our highest is ⌈two
0:27:37	Jasmine:	⌊NO what's your lowest?
0:27:39	Tyler:	My low⌈est is (.) ⌉ is fifty-five.
0:27:39	Kendall:	⌊Our lowest is ⌋ is fifty-five.
0:27:41	Jasmine:	Okay we can fit our numbers in between that.
0:27:43	Edith:	Okay lets go from ten,
0:27:45	Jasmine:	Alright and your binder is facing you so why don't you write it?
0:27:47	Edith:	It goes from thirty tah (2.8) it goes from thirty to uh >two fifty-five< so we go thirty to forty,
0:27:56	Kendall:	Thirty to forty. Forty to fifty,
0:27:59	Jasmine:	Yeah Edith's doing our (.) ⌈master plan.
0:27:59	LS:	⌊(Isn't it) thirty-nine? Is that what you are doing Edith?

0:28:02	Jasmine:	Yeah thirty to ⌈thirty-nine.
0:28:03	Kendall:	⌊Yes.
0:28:05	Edith:	Oka':.
0:28:05	Jasmine:	Cuz know forty and
0:28:06	LS:	And forty to forty-nine. And then fifty to fifty-nine.
0:28:10	LS:	So what you do is (multiply it out from anywhere)
0:28:12	Edith:	Oka:y.
0:28:14	Jasmine:	>>Quit it.<<
0:28:15	Edith:	Are we gonna ⌈do (not how)
0:28:16	Jasmine:	⌊(Kendall!) (0.3) Can you not wrinkle the paper?
0:28:19	Edith:	Okay we're gonna go=
0:28:20	Tyler:	=Em:::
0:28:21	Jasmine:	Tyler! Stop it.
0:28:22	Tyler:	OH::! You just wrinkled the
0:28:24	Tyler:	((*Pointing finger at Jasmine, Edith snaps playfully at his finger*))
0:28:25	Jasmine:	Ha⌈hahahaha heheha
0:28:25	Edith:	⌊Hahahahaha
0:28:30	Jasmine:	Did you bite him, Edith?
0:28:32	Jasmine:	Edith did you bite him?
0:28:34	Edith:	No.
0:28:34	Jasmine:	Oh, darn it!
0:28:35	Kendall:	No ( )
0:28:37	Edith:	This is confusing. How are we gonna dra- (.) how are we gonna draw this out?
0:28:41	Jasmine:	Okay here (.) let me see this. Just for a second.
0:28:44	Edith:	⌈Take my pencil↓.
0:28:44	Edith:	⌊((*Pulling a pencil from beneath the notebook*))
0:28:44	Jasmine:	⌈Well, thank you!
0:28:44	Jasmine:	⌊((*Tosses the pencil toward Tyler*))
0:28:46	Jasmine:	Okay how about thirty-ni:⌈ne
0:28:47	Edith:	⌊(not steal) Tyler Tyler!
0:28:52	Jasmine:	Thirty-nine. What are we doing?
0:28:53	Edith:	Forty
0:28:54	Jasmine:	⌈Nine.
0:28:54	Tyler:	⌊((*Tosses pencil which lands on worksheet in front of Jasmine*))
0:28:55	Edith:	Nine.
0:28:55	Kendall:	Forty to forty-nine.
0:28:56	Jasmine:	⌈↑No:::.
0:28:56	Jasmine:	⌊((*Grabs pencil off the worksheet*))
0:28:56	Edith:	THIRTY TO FORTY-NINE!
0:28:58	LS:	(I believe that's how much there are)
0:29:00	Edith:	I really: don't' understand this.
0:29:02	LS:	Thirty to thirty-nine.

0:29:05 LS: Forty ⌈to forty-nine.
0:29:05 Tyler: ⌊Three forty-nine.
0:29:06 LS: Fifty to ⌈fifty-nine.
0:29:07 Tyler: ⌊Fifty-nine.
0:29:08 LS: ⌈⌈Sixty to sixty-nine.
0:29:08 Tyler: ⌊⌊Sixty to sixty-nine.
0:29:08 Jasmine: ⌊⌊Sixty to sixty-nine.
0:29:08 Edith: ⌊⌊Sixty to sixty-nine.
0:29:09 Jasmine: ⌈⌈Seventy to seventy-nine.
0:29:09 Tyler: ⌊⌊Seventy to seventy-nine.
0:29:09 Edith: ⌊⌊Seventy to seventy-nine.
0:29:08 Kendall: ⌊⌊Seventy to seventy-nine.
0:29:10 Jasmine: ⌈⌈Eighty to eighty-nine.
0:29:10 Tyler: ⌊⌊Eighty to eighty-nine.
0:29:10 Edith: ⌊⌊Eighty to eighty-nine.
0:29:10 Kendall: ⌊⌊Eighty to eighty-nine.
0:29:11 Jasmine: ⌈⌈Ninety to ninety-nine.
0:29:11 Tyler: ⌊⌊Ninety to ninety-nine.
0:29:11 Edith: ⌊⌊Ninety to ninety-nine.
0:29:11 Kendall: ⌊⌊Ninety to ninety-nine.
0:29:12 Kendall: One hundred ⌈one hundred and nine.
0:29:13 Jasmine: ⌊One hundred and nine.
0:29:13 Edith: ⌊One hundred and nine.
0:29:13 Tyler: ⌊One hundred and nine.
0:29:14 Edith: One hundred and ⌈nineteen to an hundred and twenty-nine.
0:29:15 Jasmine: ⌊Nineteen to an hundred and twenty-nine.
0:29:18 LS: Wait a minute. A hundred and nine to a hundred and nineteen, right?
0:29:20 (Kendall): A hundred and nine,
0:29:21 LS: Now comes one hundred and nineteen to one hundred and twenty-nine,
0:29:23 Edith: And then one hun⌈dred twenty nine
0:29:25 LS: ⌊One twenty-nine one hundred thirty-nine,
0:29:27 Tyler: No::! that’s not what we were doing ⌈though
0:29:29 Kendall: ⌊Hundred thir:ty ⌈to a ⌈hundred and thirty nine
0:29:29 Tyler: ⌊No.
0:29:31 LS: ⌊Hundred thir- okay you’re right.=
0:29:31 Tyler: =No see wees: we were doing ⌈one to nine
0:29:33 Edith: ⌊Ten (.) thirty to forty, ⌈forty to fifty, fifty to sixty, sixty to
0:29:35 Tyler: ⌊We were going
0:29:36 LS: We’re going to include all the way from the very beginning? One to nine?
0:29:41 Edith: No:: no wa:it
0:29:41 Kendall: One to nine?

0:29:43 Edith: It doesn't even go that far. Tyler Tyler!
⌈It doesn't go that far
0:29:46 Jasmine: ⌊Shouldn't we just like squares you know?
0:29:48 LS: We'll let's see how many squares we ha:ve.
0:29:50 Edith: Doesn't have ⌈that big a range.
0:29:50 LS: ⌊And you said we have thirty
about thirty squares across, (.) and we have
about two hundred twenty five numb- numbers to
cover.
0:29:59 Tyler: Uh waita- yeah we should start at thirty to
thirty (seven).
0:30:01 LS: So if you have two hundred and twenty five
numbers to cover and you used one square for
each ten (.) how many squares would that use
up?
0:30:10 Kendall: Uh::
0:30:11 LS: Come on guys (.) use your use your sens:e!
0:30:15 Jasmine: Say the problem over again please huh
⌈hhh.
0:30:17 LS: ⌊You have a total of two hundred twenty-five
numbers that you've gotta fit on here (.) and
you've used ten (.) for each: (.) square say
you know zero to ten:, (1.0) ten to twen:ty
that kind of thing. ⌈How many squares would
you have altogether?
0:30:30 Kendall: ⌊Ten twenty ⌈thirty forty
fifty sixty seventy eighty ninety one hundred.
0:30:31 Jasmine: ⌊hehehe forty
fifty sixty seventy eighty ninety one hundred.
0:30:36 Jasmine: That's: twenty and then
0:30:37 Kendall: It's ten
0:30:38 Jasmine: No:: twenty makes two hundred and then you can
do five more and that would be twenty five
0:30:44 LS: So twenty five
0:30:45 Kendall: Well so if there's ⌈( )
0:30:46 Jasmine: ⌊( ) five
because you have five
0:30:48 Kendall: Two fifty five!
0:30:49 Tyler: Yeah so ⌈pfpffffff!
0:30:50 Jasmine: ⌊Remainder of five!
0:30:52 LS: You have about thirty squ⌈ares across so is
that enough to cover?
0:30:54 Tyler: ⌊Too bad!
0:30:55 Kendall: Uh: yeah.
0:30:56 LS: Well yeah, so one thing we could do is we
could start doing that. ⌈We could right over
here and we could try: (0.6) ( ) one
thru- zero through nine, ten through nineteen,
>twenty through twenty nine,< Just label them
across ↑there.
0:30:59 Tyler: ⌊((*whistling and
vigorously fanning a folded paper in LS's
direction*))

0:31:11 Jasmine: Shall we start by (tens)?
0:31:16 Edith: No:: because people are going to be looking at it (.) this: way
0:31:23 Tyler: Whoa whoa whoa
0:31:23 Jasmine: Tyler! Get off ⌈it.
0:31:24 LS: ⌊You probably want to keep it the long way so you will have enough squares
0:31:27 Edith: I know so: (.) yeah
0:31:29 Jasmine: Oh so we'll do it up instead of down?
0:31:30 LS: ↑No:↓ what I'm saying is you might do it (.) acro:ss the bottom then you can put your values (above) the numbers
0:31:34 Edith: Then put their num:bers up here
0:31:36 (0.7)
0:31:37 Jasmine: So so okay ahm::: what's our question right there?
0:31:40 Edith: Umm: thir:ty thro:ugh
0:31:42 Kendall: No no it's zero: through ni:ne.
0:31:45 Jasmine: No but we (.) we don't need that because there's zero you know?=
0:31:48 Edith: =No::::↑↑ we do:n't wa:nt it tha:t wa:y because we don't want it that way.
0:31:55 Jasmine: Ha hehe.
0:31:58 Edith: Do:n't. (0.7) Tyler! ⌈hehe
0:32:00 Jasmine: ⌊Thirty, (twenty-one over) thirty-nine. Okay. I'm going to do it much neater and write in pen. >Okay?< huhhuh
0:32:07 Edith: Wait a minute! No, you go like this (.) ⌈here
0:32:09 Edith: ⌊((*begins erasing what Edith had just written*))
0:32:11 Kendall: Just like we erased it. ((*spoken as an aside to Tyler*))
0:32:14 Kendall: You guys are crinkling the paper! ((*parody voice*))
0:32:16 Tyler: YAH, you're wrinklers!
0:32:18 Edith: Straighter than you guys did.
0:32:20 Tyler: NO:::!
0:32:21 Edith: Yeah, hunh.
0:32:21 Tyler: N:O:::!
0:32:22 Edith: Ye:ah:.
0:32:23 Tyler: No:::.
0:32:25 Edith: Yeah:.

Excerpt 5: Day 26 (0:39:15–0:44:30)

0:39:15 RL: I'm not sure I understand tha, (0.2) tha graph tha' you made: (0.3) I see it goes up, (0.8) but ⌈( )
0:39:20 Jewel: ⌊Okay:. (0.4) What- S'okay, I'll explain
0:39:23 April: We're not done yet.=

0:39:24	Jewel:	=We're not DONE with our graph yet.
0:39:25	RL:	⌈⌈Okay
0:39:25	Jewel:	⌊⌊What we have (yet), is:, okay, let's say, on our graph, it's a line chart. So we hafta have-
0:39:31	RL:	Are you sure?
0:39:32	Jewel:	Yes:, it's a line graph, so we hav:e the Xs you know?
0:39:35	RL:	Okay, ⌈exes?
0:39:35	Jewel:	⌊An' then we have tha- we hafta have ⌈tha number:s?
0:39:37	RL:	⌊Whadda these Xs mean? I'm not sure I under⌈stand.
0:39:39	Anneke:	⌊That's where the data stands.
0:39:41	RL:	Oh, ⌈okay
0:39:41	Jewel:	⌊Like- if it was eighty (one)- eighty- if it was seventy-⌈three
0:39:43	RL:	⌊So lemme- hep- help me out, by- I'm gonna have- I- I- see: something up there that's a hundred and twenty one millimeters high. Where does that come in on yer ⌈graph. =
0:39:52	Anneke:	⌊((*points to place on baseline*))
0:39:52	April:	=Ah hunerd: ⌈(hundred) an twenty one: ⌈(.) right ⌈here.
0:39:52	Jewel:	⌊Hunerd: an twenty one:
0:39:54	Jewel:	⌊((*also points to place on baseline*))
0:39:54	April:	⌊((*also points to place on baseline*))
0:39:55	Jewel:	Aroun:d
0:39:56	April:	Around there. =
0:39:56	RL:	= And how would you represent that on your graph?
0:39:58	Jewel:	⌈⌈You could (have ones)
0:39:58	Jewel:	⌊⌊((*marking an X on the baseline with her finger*))
0:39:58	April:	⌊⌊You cd' put a X like, right there.
0:39:58	April:	⌊⌊((*marks an X with her finger*))
0:39:60	RL:	So where would I put the X?
0:40:02	April:	Like- ⌈(.) like-
0:40:02	RL:	⌊Right over here?
0:40:03	Anneke:	Yeah. =
0:40:03	April:	= Well, wh' if - if- ⌈( )
0:40:04	April:	⌊((*points to y-axis*))
0:40:04	Jewel:	⌊((*points to y-axis*))
0:40:04	Jewel:	⌊It depends where the ⌈plant
0:40:05	RL:	⌊Wh- What's over here?
0:40:06	Jewel:	>We're gonna have tha< plant num:bers:. Er- like- =
0:40:09	Anneke:	= We think. =

0:40:09	Jewel:	= ⌈plant one, plant two, plant three, plant four, ⌈plant five ( )
0:40:09	Jewel:	⌊((*marking regions along y-axis*))
0:40:11	Anneke:	⌊But if it doesn’t (really) matter.
0:40:13	Wally:	Cuz it’s gonna look all wierd. =
0:40:15	RL:	= Oh you’re gonna hav:e, um so you’re gonna have sixty three ⌈different (0.5) ⌈plants: here. =
0:40:18	RL:	⌊((*pushing finger along y-ax*is))
0:40:19	Jewel:	⌊Plants.
0:40:20	(Jewel):	= Yeah. =
0:40:20	Anneke:	= Does it matter? With tha- (things are). You’re trying to figure out those: (.) tha: two answers. And it doesn’t matter what tha names of forty-six. the plants are: in those. So couldn’t you just put (.) data from (.) like Day Nineteen? Couldn’t you do that? =
0:40:35	Jewel:	= You hafta ⌈organize your data.
0:40:35	RL:	⌊Sure, you can do anything ⌈you want ( )
0:40:36	April:	⌊But then, but then, if you get it ⌈right here,
0:40:38	April:	⌊((*pointing with fin*ger to a position on the graph))
0:40:38		(1.1)
0:40:39	Anneke:	Well if it doesn’t matter. Cuz you know there’s a plant there and you know: that (.) okay, you know there’s a plant there, and >then say there’s another plant,< same height right there, and then:, you keep going on with ⌈your data.
0:40:49	Wally:	⌊(Did you take those off of ⌈there)?
0:40:49	Wally:	⌊((*flipping sheet of loose-leaf paper onto the graphing paper*))
0:40:50	RL:	⌊(Okay let me) answer your question. Like let’s say tha first plant (.) I’ll call it Plant One, and I look over I’m going to call one hundred and fifty nine, Plant One. And then I look over there: and I see: a one hundred and sixty-five, that’s Plant Two?
0:41:04	April:	Yeah.
0:41:05	Jewel:	Yeah.
0:41:05	RL:	How does it help you: answer your question,
0:41:08	Jewel:	Well but ⌈you said-
0:41:09	RL:	⌊if I call one Plant One and the other Plant Two?
0:41:13	April:	It doesn’t.
0:41:13	RL:	It doesn’t.
0:41:15	April:	But- but that’s ⌈the way a- that’s the way a li- line graph, normally is::.
0:41:16	RL:	⌊But then why are you representing ( )

0:41:21 Anneke: But thissus a bar graph.
0:41:22 RL: Did- did anyone say tha it hada be a line graph?
0:41:25 April: No.
0:41:25 Anneke: (Or at ⌈least) a bar graph.
0:41:25 Jewel: ⌊(   ) said organize the data, and that's not organiz:ed, it's not even a number or in order.
0:41:31 RL: No, that's not even (.) a number (.) you're right, it's completely unord- unordered right now.
0:41:36 Jewel: But so how are you organizing it if I write in one sixty-three, one sixty-four, one sixty-five?
0:41:42 Wally: (   )
0:41:44 RL: Well you gotta kinda figure out what you're tryin to figure out. (0.7) Okay, (.) so fix it.
0:41:47 RL: ⌈⌈((*walking away from table*))
0:41:47 April: ⌊⌊I agree with th- what Anneke's saying now.
0:41:50 Jewel: Well who wants to erase all this, I don't ⌈wanna.
0:41:52 Jewel: ⌊((*delicately pushing the graph paper away*))
0:41:53 Anneke: >No, you don't have to erase any of it.< Just put- tha (.) Day Nineteen data right down there.
0:41:57 April: That's all you have to do. =
0:41:58 Jewel: = Well we need this line to be higher. Someone get me a big eraser. ⌈April go to my locker.
0:42:01 Anneke: ⌊Jewel Jewel ya don't need to erase it. Jewel, ya don't- jus put-
0:42:05 April: Just write it down ⌈there
0:42:06 April: ⌊((*Sliding pinky of right hand along the edge of the graph paper*))
0:42:06 Jewel: No, there isn't enough room. I want it to look neat.
0:42:09 Anneke: It's gonna look neat enough, okay?
0:42:11 Jewel: Naaah!
0:42:12 April: Naa⌈ah!
0:42:13 Jewel: ⌊Erase ⌈that. Erase this.
0:42:13 Jewel: ⌊((*pointing at the axis drawn by Anneke*))
0:42:15 Anneke: ↑No why? It's fine!↑
0:42:20 April: Wally, what's no:t neat about that?
0:42:24 Wally: They're gonna get all scrunched up.
0:42:26 Anneke: (We) don't ca:re?
0:42:28 Jewel: Yah Wally, (.) >DO WE CARE?<
0:42:30 Wally: ⌈⌈The X's are gonna be like this
0:42:30 Wally: ⌊⌊((*unfolds a sheet of scrap paper and marks it with pencil*))
0:42:32 Jewel: WE'RE NOT DO:ING THAT!

0:42:35	RL:	⌈⌈((*returns and kneels next to table*))
0:42:35	RL:	⌊⌊Okay so maybe what we want tah consider (1.8) is (.) what what I think we did really nicely here (.) is that we created (.) some way of thinking about (1.5) arranging your (.) your infor:mation? (0.8) from smallest to:: largest I see. (1.2) Now:: what you have to think about iz: thatsa thatsa good start. (1.0) Ahm: now ya hafta think about how your gonna: show (0.9) each of tha: (1.1) each of the values.
0:43:07	Anneke:	Ah we just put the little Xs.
0:43:09	RL:	Okay, what wud- what does an X mean?
0:43:11	Anneke:	It means that's where =
0:43:12	April:	= That's where the (.) that's (0.4) ⌈if you go across there?
0:43:14	April:	⌊((*rising from chair and pointing out a line through the middle of the graph paper*))
0:43:15	RL:	Yeah.
0:43:16	April:	If you if you go across there that's the number of (Ns).
0:43:19	Anneke:	Yeah.
0:43:20	RL:	Okay but (.) each one of these: so it's from: (1.0) like this goes from one thirty to ⌈one thirty-eight, right? That's what
0:43:26	RL:	⌊((*redraws one of the hash marks on the ordinate of the students' graph*))
0:43:28	Anneke:	One thirty-two.
0:43:30	RL:	One thirty to one thirty-eight right?
0:43:32	RL:	Is that right? =
0:43:33	RL:	= And then ⌈that's
0:43:33	(Anneke):	⌊No (.) that's thirty
0:43:34	student1:	It's thirty.
0:43:34	student2:	Thirty.
0:43:35	student3:	Thirty.
0:43:35	RL:	Oh I'm sorry thirty:. I'm sorry. THIRTY tah thirty-eight.
0:43:40		(Anneke) Yeah.
0:43:41	RL:	So how many plants ar- go from thirty to thirty-eight?
0:43:47	RL:	One?
0:43:48	April:	(I guess) yeah. I think ⌈there's just one.
0:43:49	Anneke:	⌊There's one X and then you'd go over a box (.) and then put an X ⌈(.) right there.
0:43:53	RL:	⌊So like how many go from thirty-eight to ( )
0:43:56	April:	One.
0:43:58	Jewel:	What?
0:43:59	April:	One plant.

0:44:02 Anneke: You'd hafta go up there and find all that informa:tion.
0:44:04 RL: Okay um so::?
0:44:05 Anneke: ⌈(Get ⌈all the) information.
0:44:05 Wally: ⌊( )
0:44:06 RL: ⌊((*produces questioning gesture with both hands*))
0:44:08 RL: You don't agree with us Wally? What's your idea?
0:44:10 Wally: ⌈((*draws horozontal line across scrap paper and adds vertical swipes*))
0:44:10 Wally: ⌊We should draw a stem-and-leaf graph.
0:44:12 RL: You should what?
0:44:13 Wally: We should draw ⌈a stem-and-leaf graph.
0:44:13 Jewel: ⌊Okay draw a stem-and-leaf ⌈graph
0:44:15 RL: ⌊A stem-and-leaf? (.) ⌈Okay. Wally why don't you draw a stem-and-leaf?
0:44:15 RL: ⌊((*nods assent*))
0:44:18 Wally: ⌈Well I was trying to show them that
0:44:18 Wally: ⌊((*gestures toward Anneke with left hand*))
0:44:20 RL: Okay so if you draw a stem-and-leaf, ⌈get another piece of paper
0:44:22 April: ⌊But (.) if he did a stem-and-leaf then that there are only like two two of the same (family up there)
0:44:28 Anneke: ⌈Wally! Draw!
0:44:28 Anneke: ⌊((*passing a sheet of scrap paper to Wally*))
0:44:29 RL: Well Wally's going to do a stem-and-leaf (0.5) and you focus on your idea and then we'll (.) we'll compare them. (0.7) So I'll get different pieces of paper.

Excerpt 6: Day 26 (0:49:38–0:52:32)

0:49:38 RL: Okay go go ahead write ninety-six there.
0:49:41 Janet: Well (.) I ⌈think
0:49:42 Rene: ⌊Well we're not sure if we are gonna do this. =
0:49:43 RL: = Well go- go ahead↑ write it. (0.9) jus let's see what you have.
0:49:47 Rene: ⌈It's our final copy.
0:49:47 Janet: ⌊((*records data point on graph*))
0:49:50 Janet: I know (.) let's ⌈(go)
0:49:51 RL: ⌊Alright (.) so: ⌈that's ninety-six
0:49:53 Janet: ⌊So it's
0:49:54 Janet: I think we should do um
0:49:55 RL: No, wait a minute, (0.8) okay so now what do we know?

((*RL asks them if the value they have just recorded has any special significance*))

0:51:00	RL:	Well, (2.6) do you need (.) ⌈do you need two (1.0) dimensions to show how spread they out- out they are o:r could you do it with one?
0:51:05	RL:	⌊*((Holding up two fingers of his right hand))*
0:51:12	Janet:	Well huhh- it's: ha- well, sorta yes and sorta no. Becuz: you need to know (then) is it one plant, or is it two plants for down here. So we're going to label this like (0.8) AHM: how many plants are there are. So like it shows how many plants there and like (0.4) we're jus' like (0.3) ⌈putting them in like alphabetical order ⌈(see here's the) heights.
0:51:32	RL:	⌊Ahhuh?
0:51:34	RL:	⌊Ahhuh.
0:51:36	RL:	Okay:, (1.0) I guess I'm just not (.) sure I understand (1.0) why you need (0.4) all these things: to show ⌈(0.8) two plants =
0:51:43	Janet:	⌊Becuz: well
0:51:45	Janet:	= >Do you-< do you understand why we need the heights?
0:51:48	RL:	I understand the hei⌈ght.
0:51:49	Malcolm:	⌊Hehehehe.
0:51:49	Rene:	Yeah but ⌈(.) we had number twelve. Explain number twelve.
0:51:49	Janet:	⌊(But this::,)
0:51:52	Malcolm:	Yeah hehehehehe ⌈( )
0:51:52	Janet:	⌊°Because° (.) because (it's numbers and it's just like) ⌈okay if you put them in alphabetical or:der, ⌈well what's number twel::ve?
0:51:55	RL:	⌊Okay?
0:51:58	RL:	⌊Well what's, (.) Janet? Janet? Calm down. ((*raising hand*))
0:52:02	RL:	So (.) that I understand.
	RL:	Let's cgh- think about this >just for a second here though< what (.) let's think about the other ones if we (did) (.) another kind of graph
0:52:12	Janet:	Well we weren't =
0:52:12	RL:	= Wait for, Janet? ((*raising his hand*)) >Wait a minute.< What other people said (.) was that (.) they were going to do ah do something they called a histogram.
0:52:21	Rene:	A what?
0:52:22	RL:	So who who said they were going to some- (.) what was your other idea? ⌈We heard about (mine)
0:52:26	Rene:	⌊I ( ) for a bar graph.

0:52:27	RL:	Oh a bar graph. Okay tell me about the bar graph.
0:52:30	Kurt:	She wants to do a bar graph. ((*pointing with pen toward girls*))
0:52:31	RL:	Who wants to do a bar graph?
0:52:32	Janet:	⌈((*raises hand and smiles*))
0:52:32	Kurt:	⌊((*twists right hand, still raised from prior point, ambiguously*))
0:52:33	RL:	Janet.
0:52:33	Rene:	Janet and Malcolm. ((*pointing toward Malcolm*))
0:52:34	RL:	Oh and Malcolm.
0:52:35	Malcolm:	⌈No::,
0:52:35	RL:	⌊Okay?
0:52:36	Rene:	(Remember)
0:52:36	Malcolm:	I want to do a line graph.
0:52:39	RL:	Okay. Who votes who votes for the line graph here?
0:52:42	Malcolm:	⌈((*raises left hand*))
0:52:42	Rene:	⌊Well I'm not sure. ((*holds up both hands palms up*))
0:52:44	RL:	Okay, Rene: and (.) Janet why might you like a bar graph?
0:52:48	Janet:	I ↑like the bar graphs because =
0:52:50	Rene:	= I'm not sure.
0:52:51	Janet:	Wa:it wait if we did number one right here it would goes up to (0.5) yeah it would go over tah (0.6) nope it would be it would be ta here
0:53:01	RL:	Well lemme ask you lemme me ask this (0.9) suppose the (.) data were not about plant heights, but they were how high the rocket went?
0:53:13	Janet:	⌈⌈You'd still use it (for this) to show the different heights the different rockets went, ⌈up and up.
0:53:13	Janet:	⌊⌊((*tapping pencil in an ascending curve across graph*))
0:53:17	RL:	⌊Okay!
0:53:19	Janet:	⌈⌈( )
0:53:19	Rene:	⌊⌊And it um would be the first rocket? tha (.) first one because it's important to see (.) which one it was because (.) ahm (.) which plan- or which:: in this rocket it was because ⌈(0.7) ahm ( )
0:53:31	RL:	⌊Uh huh.
0:53:32	RL:	Well the rockets we all sent up at the same time right? or almost?

Excerpt 7: Day 27 (0:05:43–0:09:50)

0:05:43	Tyler:	There would probably be one two three four five six (.) seven eight nine ten eleven
0:05:49	Tyler:	⌈⌈ELEVEN.
0:05:49	Kendall:	⌊⌊ELEVEN. Around ⌈eleven.
0:05:50	Tyler:	⌊Around eleven out of twenty (.) plants that are ⌈(.) in this (category)
0:05:56	Kendall:	⌊Well: in around that column
0:05:58	Edith:	>I know but didn't you ⌈say ⌈that<
0:05:58	CH:	⌊Why why do you think ⌈eleven out of
0:05:59	Edith:	⌊((*pointing to the 160s column*))
0:05:59	Tyler:	⌊No we said ⌈between thes:e
0:06:00	Tyler:	⌊((*bracketing a region on the graph with his hands*))
0:06:01	CH:	Why ⌈do you think eleven out of twenty?
0:06:02	Kendall:	⌊Not necessar:ily eleven but,
0:06:05	Tyler:	Well because we just took the stuff off of here
0:06:08	CH:	Okay.
0:06:09	Kendall:	Well that's ac⌈cording to this
0:06:11	CH:	⌊How many how many out of twenty would be two fifty ⌈five?
0:06:13	CH:	⌊((*points with pen to the 250s column*))
0:06:14	Edith:	Well would you,
0:06:15	Tyler:	One.
0:06:16	Kendall:	One to zero I'd say be⌈cause
0:06:18	Tyler:	⌊yeah one tah: well one to two maybe
0:06:20	CH:	Uh huh.
0:06:22	Kendall:	One to zer⌈o.
0:06:23	Edith:	⌊So then we think they: thought that the star meant that they meant tah
0:06:27	Jasmine:	Maybe (twelve points and) to say it in a percentage wise that uhm
0:06:30	CH:	Uh huh.
0:06:31	Jasmine:	That uh °twelve° like twelve right?
0:06:33	Edith:	Yeah yeah ⌈he did heh heh heh heh heh
0:06:34	CH:	⌊Okay.
0:06:35	CH:	So ss
0:06:36	Jasmine:	So that would most likely probably be like (.) around half
0:06:39	CH:	So this so this is half of the plants?
0:06:43	Tyler:	Well (.) not exactly=
0:06:44	Kendall:	=Not exactly?
0:06:44	Tyler:	Well a little more
0:06:47	Kendall:	Little less.

0:06:47	Tyler:	Whoa wait yeah less heeh heh heh
0:06:50	CH:	Okay,
0:06:52	Tyler:	But (.) it's the most between (.) each (.) one
0:06:57	CH:	So say if I planted (.) how many plants are here?
0:07:00		(1.1)
0:07:01	Edith:	UHHH.
0:07:02	Jasmine:	>A lot!<
0:07:03	Edith:	heh heh.
0:07:05	Kendall:	I think he said ⌈sixty three. Didn't he?
0:07:06	Tyler:	⌊No.
0:07:08	Edith:	Yeah he said like sixty ↓three.
0:07:10	CH:	Sixty three?
0:07:11	Jasmine:	Yeah he said around sixty three.
0:07:13	CH:	That looks ⌈about right.
0:07:14	Edith:	⌊And now the next question says what would you do ⌈(.) to help people ⌈see one and two better?
0:07:16	Kendall:	⌊Thirty seven
0:07:18	Tyler:	⌊Twenty six.
0:07:19	CH:	So tha⌈t's sixty three.
0:07:20	Edith:	⌊Well (.) I think our graph was pretty ⌈good and since it was so similar to this one?
0:07:22	CH:	⌊So::
0:07:25	Jasmine:	Yeah.
0:07:25	Edith:	I think I don't think they need to change ⌈anything at all.
0:07:28	CH:	⌊So say we planted another sixty three plants?
0:07:32	student:	Yeah,
0:07:33	CH:	How many (0.9) in the sss one sixty to one sixty nine would you get?
0:07:39	student:	Ummm.
0:07:41	CH:	Do you think?
0:07:42	Edith:	Uhmm
0:07:43	Kendall:	Double that.
0:07:44	Edith:	Double this.
0:07:45	CH:	Double that?
0:07:45	Tyler:	⌈WHY?
0:07:45	Edith:	⌊(So its) about twenty two.
0:07:47	CH:	⌈⌈You get twenty. Hmmm.
0:07:47	Tyler:	⌊⌊WHY?
0:07:48	Edith:	Because in one batch of sixty-three plants you get eleven so with two batches you will probably get double that.
0:07:53	CH:	Okay but say say ⌈(.) say we just looked at ⌈the new plants. We got rid of this data
0:07:55	Tyler:	⌊AROUND.
0:07:56	Kendall:	⌊Say we didn't know that (.) (then).
0:07:59	CH:	And we looked at the new plants only and we have sixty-three of em how many in the one sixties?

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0:08:04 CH:       °Do you think?°
0:08:08 Kendall:  Somewhere aro:und that number ⌈(like) (.) it
                  could be more it could be less.
0:08:10 CH:                                      ⌊Around?
         CH:      Okay.
0:08:13 Kendall:  Somewhere aro:und that number.
0:08:16 CH:       Okay.
0:08:17 CH:       So around eleven or so
0:08:20 CH:       But if you planted less like twenty how many
                  do you think we would have around one ⌈sixty?
0:08:23 Edith:                                          ⌊Like
                  well if there were only twenty, I would say
                  like (.) maybe six or fa fou:r.
0:08:29 CH:       How would you how would you figure that out?
0:08:31 Kendall:  Well because ⌈uhh
0:08:31 Edith:                 ⌊Well from this side of it=
0:08:32 Tyler:    =Well we hafta do fractions first.=
0:08:35 Kendall:  =Eleven divided by
0:08:36 Tyler:    Eleven no thirty ⌈(.) sixty-three divided by
                  eleven.
0:08:39 Kendall:                   ⌊Eleven,
0:08:42 Kendall:  No:::, eleven divided by sixty-three.
0:08:46 CH:       And what would that=
0:08:47 Tyler:    =And then you time that by=
0:08:48 CH:       And what would that tell you eleven divided by
                  sixty-three.
0:08:50 Kendall:  Ummm
0:08:51 Edith:    It would tell=
0:08:53 Kendall:  =The percentage of the numbers that fall in
                  this category.
0:08:56 CH:       Okay.
0:08:58 CH:       Alright.
0:09:01 CH:       Does this graph show you that (.) pretty
                  pretty easily the percentage that falls into
                  each category?
0:09:06 Kendall:  Not really the percentage but like (3.1) the
                  amount
0:09:12 CH:       The amount that fall into each cate⌈gory.
0:09:14 Tyler:                                       ⌊It equals
                  seventeen point ⌈four six zero three one
                  per⌈cent.
0:09:16 Edith:                    ⌊What is that?
0:09:18 Kendall:     ⌊What did you do?
0:09:19 Edith:    What?
0:09:20 Jasmine:  He did(h) something.
0:09:21 Tyler:    I did the same thing as we do on ⌈morning
                  spelling on Friday.
0:09:22 Kendall:                                   ⌊What?
0:09:24 Kendall:  Eleven divided by fifty-three?
0:09:26 Tyler:    Yeah.
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0:09:27	CH:	Mmmm.
0:09:27	Tyler:	>And then< times that by a hundred.
0:09:29	Kendall:	That's impossible!
0:09:31	Kendall:	Oh yeah maybe ⌈not.
0:09:30	Tyler:	⌊Yah.
0:09:34	CH:	So seventeen percent, ↑o-kay.
0:09:35	Tyler:	No, seventeen point five. You round up.=
0:09:39	Kendall:	=So that's really not that much but
0:09:41	CH:	Um hmm.
0:09:45	Tyler:	Well it's ⌈the biggest amount that we will get for any of 'em so I would say
0:09:45	CH:	⌊Now is that
0:09:49	CH:	So does that help you talk about what the typical height would be?

Excerpt 8: Day 27 (0:22:40–0:29:07)

0:22:40	Rene:	And then they also had an average? And they got (.) one?
0:22:48	Janet:	°Wait°
0:22:49	Rene:	°>That's supposed to be that's not right.<°
0:22:51	Rene:	It ⌈(0.9) it's:::
0:22:52	Janet:	⌊Umm on their graph they said that they had (had writ) umm one hundred thousand one hundred thirty three thousand
0:23:03	Rene:	seven.
0:23:07	Janet:	Wait (0.8) oh(h) okay one million ⌈(0.5) three hundred ⌈thirty seven six-hundred nineteen
0:23:07	teacher:	⌊heh heh heh heh
0:23:09	Rene:	⌊thirty seven six hundred nineteen
0:23:12	student:	I think you ( )
0:23:14	Janet:	I think you guys forgot to divide that.
0:23:15	student:	That was (two)
0:23:16	student2:	That was ( )
0:23:16	teacher:	Uh
0:23:17	Rene:	>Divided by sixty one<
0:23:18	Janet:	I was ( ) what they said on their graph.
0:23:21	Rene:	>You divide it ⌈by sixty-one<
0:23:21	teacher:	⌊Well even if you divide it think about the number does the number make sense?
0:23:26	teacher:	If we added all these numbers up ⌈would we get a million?
0:23:27	student:	⌊No, if you look carefully it's one hundred thirty-three point seven six nineteen.
0:23:34	Janet:	That's a point?
0:23:35	student:	Yes, it is!
0:23:36	teacher:	Okay. So that makes a huge difference. The commas and decimal points if you don't write

it neatly I could see how that would make a huge difference

((*After Janet and Rene sit down, Anneke, Jewel, and April get up to discuss the graph designed by Group 3. In the Q&A session that follows, the teacher takes up some general discussion topics*))

0:28:52 teacher: How did some other people group it? How did Kurt group his? (0.4) Or we can call em the uh special word that they make up at the UW it's called a ben. (1.2) You put things into into a ben? (0.7) Carry it around with you?
0:29:03 student1: A bin?
0:29:04 teacher: Yeah a bin.
0:29:05 student2: ⌈Oh.
0:29:05 teacher: ⌊Bee eye en.
0:29:06 student1: >I thought you said< ⌈ben.
0:29:06 student2: ⌊>I thought you said ben.<
0:29:07 teacher: ⌈⌈I probably did say ben but I meant bin.
0:29:07 class: ⌊⌊Ha ha ha ha ha hah hah.

Excerpt 9: Day 28 (0:04:24–0:17:28)

0:04:24 teacher: Well what about graph helps you see ⌈(1.2) what the typical Fast Plant would be?
0:04:26 Kent: ⌊Ahm.
0:04:29 Kent: Well: ⌈•hmm
0:04:29 Kent: ⌊((*gestures toward Kristen off camera*))
0:04:30 Kristen: Well:: (1.6) they (0.2) kinda said it (0.3) ⌈here
0:04:34 Kristen: ⌊((*pointing to annotation on lower right-hand corner of the sheet where Janet and Renee had written their answer and a description of how they had produced it*))
0:04:35 Kristen: And then (0.6) also I guess I kind of (0.6) I look at it I assumed ⌈that it was that one since they kind of had circled it or put (bold) (0.7) and ⌈(together with the circle underneath) >a little bit?<
0:04:39 Kristen: ⌊((*taps hand over the stack of 160s within the table of numbers))*
0:04:44 Kristen: ⌊((*traces with her finger the arc drawn below the stack of numbers*))
0:04:48 Kent: ⌈((*repeats this tracing gesture*))
0:04:48 Kristen: ⌊Well: (0.4) we: (0.5) I guess (0.6) we: thought that was it and ⌈then:
0:04:44 Kristen: ⌊((*points once again to Janet and Renee's answer and justification*

on the lower right-hand corner of their sheet))

0:04:53 Kristen: °they put the answer down here.°

((*Kent and Kirsten offer an answer to the second assigned question pertaining to how does the graph tell you "how spread out the data is"? Kent reports that it is "Kinda hard to see that" in Janet and Renee's representation.*

On the previous day, Janet and Renee had reported to the class that they had not been able to answer question #2 using the graph that they had been assigned to present. Kurt, a student in the audience, now asks Janet and Renee to explain how someone would be better able to answer this question using their representation.))

0:07:06 Rene: Well >okay< (0.6) this is ⌈how we (0.5) how WE (0.5) decided our answer from theirs because we wrote the answer and how we did it and they didn't.

0:07:08 Janet: ⌊Rene

0:07:16 Janet: And also, they had a different (0.6) they thought (0.5) or they think the sss sss like how spread out the data ↑is is different from what we ↑think (0.5) because they: (0.6) here (0.8) they think that it's like (0.6) like (0.8) its' (0.3) how many numbers there are in between.=

0:07:37 (Kristen): =No that's what you thought

0:07:38 student: Ye⌈ah

0:07:38 student: ⌊Yeah.

0:07:39 student: Yeah.

0:07:39 Janet: No:::.

0:07:40 Kristen: You know what we (0.5) what we thought ⌈was

0:07:42 Janet: ⌊Let me finish.

0:07:43 Janet: No wait okay (.) it's what (.) they ↑thought is that the numbers that we had (0.4) >you take< (0.6) the lowest and like count the numbers not including doubles is that what it was?

0:07:54 Janet: Wasn't it?

0:07:55 Kristen: Hmn.

0:07:56 student: What?

0:07:56 (Kristen): No we thought that (0.3) if if you started at thirty and you look at (0.4) two hundred what would ⌈(.) fifty-five?

0:08:02 student: ⌊ Fifty-five.

0:08:03 (Kristen): That's a pretty far way apart (0.4) so you'd think they're kind of spread out (0.7) cuz (0.5) between both of em it's (1.0) or if you looked a(HH)t our graph (.) there's a pretty long line of numbers that are different from each ↑other (0.8) and that's how we thought they were very spread.

0:08:20 Janet: And ↑we thought it becuz: (0.4) the (0.7) numbers (0.4) that are in between ↑thirty (0.8) and two hundred fifty-↑five (0.6) so it would be like (0.7) even it they're not up there, it would be like thirty, thirty-one, °thirty-two,° thirty-three et cetra.

0:08:36 Rene: And ⌈and we got (0.4) instead of two hundred and fifty-five we got two hundred twenty five because (0.5) we didn't start on one we started on thirty

0:08:36 Janet: ⌊And so

0:08:45 Rene: So (0.8) if we: (0.4) so if we: did start on one (1.5) so if we did start on one then there would be two hundred two hundred and twenty-five and so (0.4) since we didn't we just did two hundred twenty-five minus thirty and then

0:09:00 Janet: We did two hundred fifty five.

0:09:02 Rene: Two hundred fifty-five °minus° (0.6) ⌈thirty

0:09:04 Janet: ⌊And that equals ⌈two hundred twenty-five.

0:09:05 Rene: ⌊Two hundred fifty-five.

0:09:06 Janet: So we took the highest minus the lowest equals (0.4) is what we think how spread out they are.

0:09:12 student: Yeah but couldn't you do a (   ) graph (though)?

0:09:15 Janet: ⌈⌈NO.

0:09:15 Rene: ⌊⌊No.

0:09:17 Janet: >Okay.< (0.6) we: kne:w: (.) how to get it but then we (0.4) in some ways like (0.6) >okay.< we asked them some questions, but then they asked us .h how did you get that? So that's how sort of (0.6) that's the only thing that we could figure out (0.5) how they

0:09:33 student: ⌈⌈Got how spread out it was

0:09:33 Rene: ⌊⌊Did it?

0:09:35 Janet: Becuz: they asked us how we: got ow- (0.5) our answer for that:? And: um: it din' really (1.0) to them it- (0.5) theirs didn't make sense and .h to us (0.9) >Okay.< to them, (.) ours: didn't make sense and .h to us: (.) their's °didn't make sense.°

0:09:50 Rene: But (.) what helped us the mo:s::t wha- (like actually like/guys actually like) would've helped us the most (0.5) was if you guys like (.) wrote the answer in (0.7) showed how you did it.

0:09:59 Janet: Yeah we found that really ⌈( )

0:10:00 teacher: ⌊So you like yours because (0.3) you have the

0:10:02 (0.6)

0:10:02 Janet: Question ⌈the answer.

0:10:04 teacher: ⌊The answer written out there your ⌈typical and your thing.

0:10:05 Janet: ⌊and how to get it.

0:10:07 teacher: Okay.

0:10:08 (Kristen): ⌈⌈What what

0:10:08 Kent: ⌊⌊Yeah cuz if they didn’t have that there we would be clueless.

0:10:11 (Kristen): Yeah ⌈because this is

0:10:11 teacher: °Okay.°

0:10:13 teacher: So if you just had and your saying well if we just had to use the <graph> (0.3) ⌈data

0:10:16 Kristen: ⌊Yeah you’re supposed to be like

0:10:16 Kent: ⌊( ) we’re lookin’ for

0:10:22 (Kristen): We’d be we’d be way of⌈f.

0:10:22 teacher: ⌊Okay.

0:10:22 teacher: Thank you for sharing=

0:10:23 teacher: =Let me ask you a ques: let me ask >people a question<=

0:10:25 teacher: You guys can sit down.

0:10:28 teacher: Um: I’m wondering which graph would show: better (1.3) the spread?

0:10:33 teacher: So let’s let’s ignor:e two hundred and fifty-five for a minute and say instead of that plant being >two hundred and fifty-five< (0.5) it was ⌈five hundred fifty five.

0:10:39 teacher: ⌊((*writing “555” on board*))

0:10:42 teacher: Oka:y. Does that does that feel like it’s quite a bit different (0.4) than two fifty-five ’kay?

0:10:47 teacher: So would you say would everybody- would anybody disagree that then would become a much bigger spread if we included that number?

0:10:52 student: Hmm ↑yeah um hmm.

0:10:54 teacher: Does >anybody< say that it wouldn’t be a bigger spread?

0:11:00 teacher: >Okay.< So let’s pretend this is five fifty-five and then >so they have< just era:se this two and put five there. (0.4) Would this graph help you see that (0.3) that’s more spread (2.2) out? (0.7) Is there a graph up there that might help let say we did it >let’s say

		we did to this one< we put five fifty-five right here on the end.
0:11:18	teacher:	Would that >would the graph itself< if you (0.3) could see that or if we did it on this one we had five fifty-five here. (2.9) Is there is there a graph up there that would be better to help you see that spread? than some other ones, and why >would it be< (.) why why would that graph help you see the spread better.
0:11:38	teacher:	Jewel? (1.0) What do ya' think, yeah go ahead.
0:11:42	Jewel:	Um. Well I think that this (.) group's (0.9) it might be >harder to read from far away< but I think it's really good because (0.6) you can like tell if like (1.1) if it goes farther like (0.4) I think >(their's is good)< but they kind of like put it in the square instead of having it in the li:n:e, (0.8) (you know) it's kind of like (.) >I don't-< (.) >isn't it-< (.) it looks sort of like (0.4) you down to here an down to here °>(an that will make the biggest difference)<°
0:12:09	Janet:	We wanted people to be able to s⌈ee the numbers and if we made em like (0.4) small:, it's hard to read and (.) so that's why we made em big or either we would've drawn on the line,
0:12:11	Rene:	⌊See: it.
0:12:21	Janet:	Bu⌈t we didn't have enough room on the paper, °(to describe em)°
0:12:22	Rene:	⌊But we didn't have enough room.
0:12:26	teacher:	Okay so Jewel you think (.) this graph by looking at it if I wrote the number (.) ⌈five-hundred fifty-five right here*)* would be the (.) easiest graph to look at to see that (.) this has a lot of spread.
0:12:30	teacher:	⌊*((pointing to corner of Wally's "stem-and-leaf" graph shown in Fig. 2.2))*
0:12:38	teacher:	Is that what you think?
0:12:39	Jewel:	°Um hm.°
0:12:40	Jewel:	°Yes.°
0:12:41	teacher:	Kerri.
0:12:48	Kerri:	⌈⌈*((pointing to Group 3's graph shown in Fig. 2.5))*
0:12:48	Kerri:	⌊⌊Well I think that probably this graph because (.) it lea- they still leave: (0.9) some spaces there, (0.8) in case there would be even though there's not, so that you can (.) really see how spread out it is because it (0.5) goes (0.3) thirties, (0.5) up to the

		most and you can see if when there's like (0.7) >how much< ⌈space is there between it
0:13:07	teacher:	⌊OH::.
0:13:09	teacher:	>I see what you're saying< you're saying that there's some there's a scale down ⌈here on the bottom (2.1) an:d if it was five-hundred fifty-five they would well two-fifty's here so we'd figure it would be five fifty-five would be out ⌈here?
0:13:12	teacher:	⌊((*pointing to x-axis of Group 3's graph*))
0:13:21	teacher:	⌊((*pointing to a projected point beyond the end of Group 3's graph*))
0:13:21	Kerri:	°Yeah.°
0:13:22	teacher:	And then ⌈then you would see that number out there, and then it the graph itself would actually look like spread?
0:13:23	Kerri:	⌊H(hh)●
0:13:29	teacher:	SO en and and what helps you see the spread? (0.8) then?
0:13:35	teacher:	>What else what helps< people see that spread if if what (0.5) um: (1.6) Kerri is saying is true Ian?
0:13:41	Ian:	Uhm (1.3) no::t, not just the numbers that we actually measured that are in between, (0.4) bu:t all of the numbers that (.) are in between.
0:13:51	teacher:	SO:: this (0.2) having a scale down here, which is >one two three whatever it is,< (1.4) would help you see spread (.) better?
0:14:01	Ian:	Yeah.
0:14:02	teacher:	Does anybody not quite understand what Ian is saying?
0:14:07	teacher:	So if we were tah-to
0:14:08	teacher:	((*pointing to Group 3's 10-bin graph shown in Fig. 2.5*))
0:14:09	teacher:	What what he's saying is if we have two fifty here, the next (.) this is two fifty to two fifty-nine, and then it'd be two sixty to two seventy, two eighty to two ninety, and we're-we keep going up (0.7) and how far >would I have to go up< until I got ⌈five-hundred and fifty-five?
0:14:21	teacher:	⌊((*waving hand in direction of the projected point beyond Group 3's graph*))
0:14:25	teacher:	Wally?
0:14:27	Wally:	Um:: (0.6) I think thirty-one times?
0:14:32	teacher:	Ok, what >would the what would the what< would the scale say over here when I got it?
0:14:35	Wally:	Umm.
0:14:37	teacher:	To that part?

0:14:38 Wally: Five-hundred fifty to five-hundred sixty?
0:14:42 teacher: Yeah. so we'd have to continue on here to five-hundred and fifty ⌈to five-hundred and fifty,
0:14:44 teacher: ⌊((*extending the x-axis across the board to the right of Group 3's graph*))
0:14:46 student1: Nine.
0:14:47 student2: Nine.
0:14:46 teacher: Ni:ne and then there'd ⌈be a five fifty-five right above it.
0:14:49 teacher: ⌊((*marking a point on the board directly above the projected x-axis*))
0:14:52 teacher: >Then that then that< then that would look pretty spread out, wouldn't it?
0:14:55 teacher: >Does anybody< disagree that it would look spread out if we uh (0.9) we had a scale?
0:15:00 teacher: Whereas on this one, all we'd have to do is, ⌈erase this (0.4) and put a five there (0.3) and we just leave it there right?
0:15:02 teacher: ⌊((*pointing at entry on tabular representation produced by Rene and Janet*))
0:15:07 teacher: So maybe this one doesn't help you see: how ⌈spread out it is as well.
0:15:09 ⌊((*spreading arms out*))
0:15:11 teacher: Uh (0.7) as ⌈that type of a graph.
0:15:13 teacher: ⌊((*pointing to the 10-bin graph of Group 3*))
0:15:15 teacher: And like Ian said, so long as you have a scale on the bottom, I think that helps people determine how spread something is.
0:15:21 teacher: Kristen?
0:15:22 Kristen: Well I'm not (0.6) sure but (0.5) I'm not I don't (0.9) well (0.5) I think (0.7) this: (0.9) graph might help you, ⌈down there because of the
0:15:32 Kristen: ⌊((*reaches toward and touches Kurt and Malcolm's graph*))
0:15:34 Kristen: like the line (0.2) up here (0.6) might get higher ⌈but I'm not sure how this graph works really but ⌈(   )
0:15:37 student: ⌊Just like
0:15:41 teacher: ⌊Let's put this one up cuz this one,
0:15:43 Kristen: Yeah ⌈I didn't I didn't really understand the graph very well
0:15:44 student: ⌊Can I go up there?
0:15:44 teacher: ⌊((*detaches Kurt and Malcolm's graph from the board and moves it into a more visible position*))

0:15:48	student:	Can I show her some °(high percentages)°?
0:15:50	teacher:	Ha- (0.5) Kurt you made this graph and Malcolm right?
0:15:53	Kurt:	Yeah.
0:15:53	teacher:	What would five fifty five look like on this graph?
0:15:57	Kurt:	It would be like up to (this) =
0:15:58	teacher:	= They would (0.3) the the way you read their scale (0.3) is you have the numbers on the side >fifty sixty seventy< so they >had this< and (.) what is that?
0:16:06	teacher:	Over here >ten ⌈twenty thirty forty fifty sixty seventy eighty ninety< a hundred, (0.8) a hundred and ten a hundred and twenty
0:16:07	student:	⌊Oh::!
0:16:12	student:	That's
0:16:13	teacher:	Caleb?
0:16:14	Caleb:	The Y-axes?
0:16:14	teacher:	That's the Y-axes and its also an,
0:16:18	teacher:	April?
0:16:19	April:	Bar graph.
0:16:19	teacher:	It's a bar graph,
0:16:20	April:	But (.) but
0:16:22	teacher:	And they've done something else to it they just didn't write (0.8) >there's< something else that's special about it (0.8) that would help (.) that ⌈you'd also be able to see it
0:16:28	teacher:	⌊((*pointing on Kurt and Malcolm's graph with stick*))
0:16:30	teacher:	Ian?
0:16:31	Ian:	You can tell how high it is
0:16:32	teacher:	Well how can you tell how high it is?
0:16:33	Ian:	(Start)
0:16:34	teacher:	What ⌈did they do to it?
0:16:34	Ian:	⌊Cuz it's higher on the (.) graph
0:16:38	teacher:	Because they,
0:16:40	Ian:	Put a scale?
0:16:40	teacher:	Yeah, they could put a scale on
0:16:43	teacher:	So five hundred they get to a ⌈hun- (0.3) what do they got up here two fifty?
0:16:44	teacher:	⌊*((pointing to top of y-axis of Kurt and Malcolm's graph with a meter stick))*
0:16:46	teacher:	So five hundred would be (.) twice as high.
0:16:50	teacher:	So it's gonna be up there somewhere so would that (.) that scale helps you see will help you see how high it is.
0:16:56	teacher:	Is that what you =
0:16:57	Kristen:	= I think (.) I think that one and that one would probably help.

0:17:00	teacher:	So are are we agreeing that scale's an important then?
0:17:03	Kristen:	Yes. =
0:17:03	teacher:	= To see how to help see how spread something is?
0:17:06	student:	°Isn't ( )°
0:17:08	teacher:	Wally?
0:17:09	Wally:	There was <u>one</u> thing that confused me at first on that that (0.5) UM: (0.3) there was like a bar graph for part of it and then ⌈there was just lines with little platform things
0:17:06	student:	⌊No. But you got (these things)
0:17:19	student:	It got too short so I had to ( )
0:17:27	teacher:	Okay,
0:17:28	teacher:	Ah: we need another >somebody else to come up< and share another graph.

Excerpt 10: Day 28 (0:18:50–0:22:03)

0:18:50	Ian:	On this graph? (0.9) what they did is um (1.5) it's a little bit confusing (0.6) sort of um (1.2) what they did is (0.8) um (1.9) they had the tens column going up the side on the Y axis and then they had the ones (1.3) um (digit) going down the (0.9) like (0.9) um X axis so (.) like one hundred twenty five would be like (1.2) there (1.2) cuz you find one hundred twenty,
0:19:28	teacher:	Hm hmm.
0:19:29	Ian:	(Go) down one
0:19:32	Ian:	And
0:19:34	student:	Oh::!
0:19:34	teacher:	So you like it ca can I say this Ian? You would like it if the graph was turned maybe
0:19:42	teacher:	⌈⌈((*removing tape attaching graph to chalkboard*))
0:19:42	teacher:	⌊⌊If you ignored the words and get (.) you would rather you'd prefer it to be kinda like ⌈this?
0:19:45	teacher:	⌊((*retaping sheet to board after having rotated it 90°*))
0:19:47	teacher:	Is that what you are saying so we've got the tens going along this way well they're actually backwards going this way and then the axis going up (1.2) like that?
0:19:57	Ian:	Well I'm not su:re.
0:19:59	teacher:	Okay.

0:20:02	teacher:	⌈⌈Cuz then it then it starts to look more like what another group started getting.
0:20:02	teacher:	⌊⌊((*rotates sheet of paper back to it's original orientation and re-tapes to board*))
0:20:08	Ian:	But I think it it's neat how they did it.
0:20:13	teacher:	Okay.
0:20:13	teacher:	What about it helps you guys see that the numbers are (.) spread and that they're uh
0:20:20	Ian:	Well:: =
0:20:20	teacher:	= >What a typical fast plant would be?< =
0:20:22	Kerri:	= Well to see how they're spread you have to look up at the highest one (0.5) and then if they're (0.7) so then like on the highest line (0.8) that would be like (in) the highest (1.0) like the (0.4) highest one and the lowest (0.5) would be down here (0.4) and if there's one along the same line then you just look to see how far out this way it is
0:20:45	Kerri:	So if it ( )
0:20:47	Ian:	Or =
0:20:47	teacher:	= Ca can you guys circle on there where where wherever you guys think a typical Fast Plant is? by looking at the graph?
0:20:53	Ian:	I think would be somewhere in the middle.
0:20:55	(Cindy):	Wouldn't it be somewhere ⌈(in the middle?)
0:20:57	(Ian):	⌊( )
0:20:59	Ian:	It would be like in the middle.=
0:21:01	teacher:	= Well yer okay Ian your saying the middle I saw Kerri ssa kept pointing to something with a with a ⌈(0.7) ⌈squares all around it. =
0:21:06	Kerri:	⌊It would be ⌊(over here)
0:21:06	Student1:	= Use the key! =
0:21:07	Student2:	= There's a key it's at the top
0:21:09	Kerri:	Look at the key.
0:21:10	Ian:	That means there's three der or four der
0:21:13	Kerri:	There's (.) four of that number ⌈so
0:21:15	Ian:	⌊There's actually fi:⌈ve.
0:21:16	Kerri:	⌊And (0.7) I know.
0:21:18	Ian:	Hehh
0:21:19	Kerri:	And X (.) means one of them, star (0.9) means there's two::, (0.4) that one (0.9) this with the box around it? is three and that is four (1.2) so:: you look to see like (.) (if) the different symbols? (1.1) and that's one (0.9) that's the biggest number=
0:21:44	Ian:	=I think to find the um a typical one you'd look like toward the middle of the graph? and find a point that was closest to the middle? (0.7) because then up and down you'd find the middle and side to side you'd find the middle=

0:21:57 teacher: =So would you say that yer >I think you said< the typical was probably this one or would it ⌈would you use
0:22:01 Ian: ⌊Somewhere around there.
0:22:03 teacher: Okay.

Excerpt 11: Day 28 (0:30:33–0:31:22)

0:30:33 Michael: I have a question for Ian’s group (1.4) in it (0.6) wasn’t it kind of hard to make it? (1.3) like to figure out those squares and everything (0.9) to mark those numbers?
0:30:47 student1: How how did you get your idea for that? =
0:30:49 Michael: = Yeah. =
0:30:49 student1: Cuz I mean it’s not something that jus pops into your ⌈(.) head like that
0:30:52 student2: ⌊Heh: heh heh heh.
0:30:56 Kerri: Well:: we jus:: (0.8) we were thinking about different graphs, that we could make like bar graphs and stem and leaf and stuff. And we didn’t really (1.3) like (0.5) how we did that, (0.6) how to do that really (0.6) so we jus (0.4) started to think up new ideas that would work and make it.
0:31:18 student1: You wanted it to have like it’s an original graph? Because I’ve never seen that one before.
0:31:22 Kerri: Heh heh heh heh heh heh.

Excerpt 12: Day 28 (0:42:23–1:00:56)

0:42:23 Tyler: Okay. (1.0) what we realized (.) that (.) um: (.) this: (0.5) this basic⌈ally was the exact same (0.5) as ours.
0:42:29 Tyler: ⌊((*taps knuckles of right hand against posted graph from Group 2*))
0:42:31 Tyler: ⌈⌈((*walks across front of room*))
0:42:31 Tyler: ⌊⌊They had the same idea (.) as (.) we did.
0:42:35 Tyler: ⌈⌈((*points with right hand to the graph created by Group 3*))
0:42:35 Edith: ⌊⌊Except when they did it (0.6) they didn’t do like thirty through forty (0.8) they just had it (0.5) if this was under thirty (0.4) then you’d put ones under thirty (0.6) thirty through thirty-nine.
0:42:46 Tyler: Well (0.5) no they I think they meant
0:42:49 Kendall: All the thirties (0.6) ⌈all the forties all the fifties
0:42:51 Tyler: ⌊all the for⌈ties all the fifties and all the sixties
0:42:52 Jasmine: ⌊Yeah.

0:42:59	Tyler:	Well actually
0:43:01	Tyler:	⌈⌈((*grasps Kendall and pulls him by the sleeve in the direction of the Group 3 graph*))
0:43:01	Kendall:	⌊⌊What? What? ((*whispered*))
0:43:02	Tyler:	Ahm: (0.5) it's the (0.5) actually it went (2.0) actually that does mean the same thing becaus:e (1.3) fifties only gaw up to fifty-nine. They don't go up to sixty. (1.0) ( ) (1.3) But we did that differently so
0:43:25	Jasmine:	And um: alright (0.6) the first question was (0.6) fin:ds (0.7) uh (1.1) like (0.3) for a middle number
0:43:33	teacher:	How does the graph ⌈help you see::? ⌈(1.1) what what's typical what usually happens on Day Nineteen?
0:43:34	Jasmine:	⌊(explain)
0:43:35	Edith:	⌊Their graph really helps us (1.0) their graph really helps because down here it says: (0.6) a star equals the most common number and so you just look ⌈under ⌈here and it says =
0:43:44	Tyler:	⌊Yup. They ⌈show a star ( )
0:43:44	Jasmine:	⌊((*highlights a line down the center of the graph*))
0:43:45	Edith:	⌊((*points with pinky to the bottom of the Group 3 graph*))
0:43:46	Tyler:	⌊((*points to bottom of graph*))
0:43:46	Edith:	= everything under one sixty is the most typical
0:43:49	Edith:	So that's what they thought and then the star's right there so (1.0) And (.) an (I guess that's how ya) find that out.
0:43:57	Kendall:	And then ⌈how (.) spread (.) out the data is
0:43:57	Edith:	⌊How spread
0:44:01	Edith:	Just ⌈look at (from there to ⌈that)
0:44:01	Edith:	⌊((*points to the left end of the data range and then to the right*))
0:44:02	Jasmine:	⌊((*points with Edith to the right end of the data range*))
0:44:02	Kendall:	Yeah.
0:44:03	Edith:	The beginning and the end of the graph.
0:44:12	Jasmine:	Um:: Janet,
0:44:14	Janet:	Well okay so: (0.7) the numbers that are in the bottom? the like
0:44:19	Jasmine:	((*points with right hand toward the number scale on the bottom of the graph drawn by Group 3*))
0:44:20	Janet:	Yeah those, (0.5) um:: (0.4) so those are sa- (.) saying, (1.1) the:: (0.5) anything that's under that number?

0:44:30 Kendall: Any thing ⌈yeah (1.3) like anything under thirty,
0:44:30 Jasmine: ⌊YEAH kinda like ours ⌈it's like
0:44:32 Jasmine: ⌊((*points and waves hand in direction of the Group 2 graph*))
0:44:34 (April): Like if it if the number under there was thirty, anything in the thirtys:: goes: under there.
0:44:42 Edith: And so then we started with ⌈four so =
0:44:43 Edith: ⌊((*gestures toward first column of graph*))
0:44:43 Janet: You mean so like (0.5) any (0.5) thing in the thirties goes in that umn?
0:44:49 Edith: Yeah.
0:44:49 boy: Yeah.
0:44:50 Edith: From thirty (five).
0:44:52 Jasmine: Any other questions?
0:44:55 CH: Yesterday when you where talking about this graph, you talked about it a different way of thinking about the typical, (0.5) what would be the- the typical value? (1.0) and you were using percentages, (0.6) can you, explain that Kendall? (0.5) Remember that idea?
0:45:09 Kendall: Oh: (0.9) like (.) ⌈the:: highest I think is eleven in this: (0.9) column (0.7) ⌈an:d
0:45:10 Kendall: ⌊((*pointing at the column with most members*))
0:45:14 Edith: ⌊And then we did how many numbers ⌈there were
0:45:16 Edith: ⌊((*signifying the column by waving finger over it*))
0:45:18 Edith: ⌈⌈And then we divided
0:45:18 Kendall: ⌊⌊And then we divided (.) an found a percent and,
0:45:23 Edith: What (.) was: it?
0:45:24 Edith: Wuz it like, =
0:45:25 Jasmine: = It was like ⌈seventeen point something something something
0:45:25 Kendall: ⌊seventee:n point
0:45:27 Kendall: But I didn't =
0:45:29 teacher: = Okay wait I'm not >I'm not< sure I follow are you saying then, (0.7) seventeen percent of all the numbers (.) ⌈fall in here?
0:45:35 teacher: ⌊((*sweeps finger over the column with most members*))
0:45:36 (Edith): Yeah.
0:45:36 Kendall: Yeah.
0:45:36 Tyler: No:, they fall under um:: ⌈YEAH, ⌈they fall under =
0:45:38 Tyler: ⌊((*repeats teacher's gesture*))
0:45:38 Edith: ⌊Yeah.

0:45:39	Jasmine:	= Hehehe⌈hehehe,
0:45:39	Edith:	⌊He(•hh)uh
0:45:41	Edith:	Okay-
0:45:42	Tyler:	I thought it was just one sixty but it was (all of them)
0:45:47	Kendall:	But:, I really don't think that's like enough (1.3) of the: percent (0.3) tah: (0.4) is- as a typical number because that's like pretty low from a hundred? (0.6) so: then ⌈we (0.8) tried adding all ⌈these,
0:45:58	Tyler:	⌊but still
0:46:00	Kendall:	⌊((*indicates with finger the two columns adjacent to the one with the most members*))
0:46:02	Kendall:	Which would- (0.8) then we had twenty-two numbers there and then we got (1.0) thirty-four percent? And (1.8) we sorta thought that that was more like
0:46:13	Tyler:	So we thought that (1.1) ⌈out of these three were the ⌈typical area?
0:46:17	Tyler:	⌊((*points toward the three columns previously indicated by Kendall*))
0:46:17	Tyler:	⌊((*uses both hands to create a frame around the three columns*))
0:46:19	Tyler:	That's what we thought. =
0:46:20	teacher:	= So that's kinda like somebody came up here the oth- (0.8) yesterday and circled (1.1) I don't know who it was it was April I think it was (0.4) said the ⌈typical: Fast Plant >day nineteen< was going to be right around here >was that you April?< =
0:46:29	teacher:	⌊((*circles the center three columns in the "Brassica Rapa Graph" prepared by Group 3 and presented the previous day*))
0:46:31	April:	⌈Yes.
0:46:31	teacher:	=⌊you circled (0.3) ⌈those kind of those numbers that group of numbers?
0:46:32	Tyler:	⌊((*points to the column with the most elements on the Group 3 graph*))
0:46:35	April:	Eh hm:.
0:35:36	teacher:	And then you're ⌈saying that same thing that's (0.3) twenty (.) was it twenty-two percent?
0:46:36	teacher:	⌊((*pointing toward Kendall*))
0:46:40	Tyler:	⌈⌈Yeah.
0:46:40	Kendal:	⌊⌊Twenty-two number.
0:46:41	teacher:	Oh twenty-two number what percentage of
0:46:43	Kendall:	⌈⌈Thirty (0.2) four.
0:46:43	Tyler:	⌊⌊Thirty

0:46:44	Tyler:	Thir⌈ty-four
0:46:44	teacher:	⌊So thirty-four percent of the Fas:t Plants ⌈fall: somewhere in (.) this area?
0:46:47	teacher:	⌊((*circles the three tallest columns on the Group 3 graph*))
0:46:52	teacher:	So you're you're saying that if you grow a Fast Plant chances are go:od Kendall, >would you say chances are good< that it's going to be (.) between a hundred and fifty and a hundred and seventy? because that's where thirty percent of all the stuff was?
0:47:02	Kendall:	Yeah somewhere around there.
0:47:04	teacher:	What about this: one? (0.9) what what what's the per- what's the odds of it? >of your Fas< Plant growing two hundred ⌈and fifty-five? (1.5) millimeters (0.3) would you say that's um: (.) pretty good?
0:47:10	teacher:	⌊((*points at the single data point at the right side of the graph prepared by Group 3*))
0:47:15	Tyler:	I would say (0.3) well °well° ⌈it would be one out of (0.7) sixty.
0:47:17	Kendall:	⌊I would say
0:47:21	Tyler:	I would say it would be one out of sixty three.
0:47:25	teacher:	What's the percentage of that happening?
0:47:27	Tyler:	Well- (0.3) ⌈one out (0.4) wait
0:47:27	Kendall:	⌊Ah::
0:47:29	teacher:	>How would you< (.) how would you figure out the percentage of that happening?
0:47:32	Jasmine:	((*hands a calculator to Tyler*))
0:47:35	Tyler:	Okay, (1.8) okay three,
0:47:45	teacher:	Can- can somebody tell us tell us what Tyler is doing on the calculator right now? (0.5) some body in that group?
0:47:49	Kendall:	He did (0.5) one divided by (fifty) three ⌈(1.0) and then ⌈he did
0:47:53	teacher:	⌊((*writing these numbers on side board*))
0:47:54	student:	⌊That's one.
0:47:55	Tyler:	That's (0.7) yeah I meant it's: (1.4) one point five (0.4) percent.
0:48:01	Kendall:	Well then he ⌈(0.6) did ⌈times
0:48:02	Tyler:	⌊Of a chance.
0:48:03	teacher:	⌊So you have one percent chance of your Fast Plant growing two hundred and fifty-five millimeters?
0:48:09	Tyler:	Well one (1.0) yeah ⌈(0.6) basically yeah.
0:48:11	teacher:	⌊oh
0:48:14	Kendall:	But I think it it'd be (0.7) more typical (0.4) than even than ⌈that that before you would grow a ⌈thirty because (.) that's (0.3)

real closer to these numbers (0.4) and this would get like (0.8) way out here and there's like no numbers in between there,

0:48:18 Kendall: ⌊((*points at 255 value on right end of number scale*))

0:48:20 Kendall: ⌊((*points at the value 30 on the left end of the number scale*))

0:48:31 Janet: Well- oh yeah, I have a question (1.0) when you said that there was nothing growing in the fifties, sixties, and seventies? (1.0) Well: what about the tens:? The tens are the second highes:t. (0.9) How come you didn't say those?

0:48:45 Rene: What tens?

0:48:46 Edith: Yeah that was (the question I had).

0:48:52 Tyler: What?

0:48:54 Janet: Okay- you ⌈said

0:48:55 Rene: ⌊A hundred and ten.

0:48:56 CH: A hundred and tens, Janet?

0:48:57 Janet: Yeah, a hundred and tens.

0:48:59 (Tyler): ⌈Wha:t?

0:48:59 Tyler: ⌊((*points at one tens column on Group 3 graph*))

0:48:59 Edith: ⌊((*points at one tens column on Group 3 graph*))

0:48:59 Jessica: ⌊((*points at one tens column on Group 3 graph*))

0:49:00 Janet: Okay- you ⌈said

0:49:01 Jasmine: ⌊Right here?

0:49:02 Rene: Oh right here

0:49:02 Rene: ((*rises from seat and points at Group 3 graph*))

0:49:02 Janet: You said that (0.5) well that the typical would be the one fifties, one sixties, and one seventies. (0.8) But the hundred and tens are (.) the second highest, (0.3) how come you ⌈didn't

0:49:15 Tyler: ⌊We're ⌈(0.3) we're we're just picking an ⌈are:a

0:49:15 Edith: ⌊See Janet even ⌈like this um (0.5) yeah

0:49:16 Edith: ⌊((*gestures toward the 170 column*))

0:49:17 Tyler: ⌊((*gestures toward the 170 column*))

0:49:18 Tyler: We don't want it to be (0.6) ⌈this much (1.1) because that's (0.4) too ⌈(going too far)

0:49:20 Tyler: ⌊((*sweeps right hand in circular motion over middle of graph, then uses both hands to segment middle of graph*))

0:49:22 Edith: ⌊It would be really

confusing if you ⌈said that it's ⌈this one and it's this one and it's this one.
0:49:25 Tyler: ⌊So it is this
0:49:25 Tyler: ⌊((*uses two hands to bracket the 170 column*))
0:49:25 Edith: ⌊((*runs finger down the 110 column, repeats on two adjacent columns*))
0:49:27 Rene: At least there's not any gaps between there so why ⌈not.
0:49:29 Tyler: ⌊Yes there is. ⌈This is a huge gap between ⌈these
0:49:30 Tyler: ⌊((*slaps palm against middle of graph*))
0:49:31 Tyler: ⌊((*points to the 110s column and the 170s column*))
0:49:32 Rene: Not any zero: gaps though so why not?
0:49:36 Tyler: Well (0.9) ⌈cuz (1.7) yeah
0:49:37 Edith: ⌊( )
0:49:37 Jasmine: ⌊( ) well some are data.
0:49:40 Tyler: That'd be (0.7) if the typical that would be like seventy percent would be the typical.
0:49:47 Rene: It probably is!
0:49:49 teacher: Let's try figuring something out which is this (3.2) whoa Michael what's wrong?
0:49:57 Michael: Um (0.8) I noticed that the hundreds- tha (0.5) hundred and seventies and the hundred and tens on (0.5) Kendall's, group's graph explained (0.4) were the same height but on (0.5) the other one, the hundred and tens have one more.
0:50:14 Tyler: Yeah I know we did- we ⌈didn't
0:50:15 Kendall: ⌊Is their's a little wrong?
0:50:17 Tyler: Yeah we put too many (0.8) because uh: (1.2) we were (1.4) we were kind of (.) misorganized we were doing it a little (0.5) we were doing it a different way than we usually do it, well than you'd think we'd do it,
0:50:32 students: hmm hmm hmm
0:50:33 teacher: You're saying there's ⌈there's an error >up there< ⌈you have too manys (0.3) too many in the hundred-tens?
0:50:34 Edith: ⌊ha HA
0:50:35 Tyler: ⌊No!
0:50:38 teacher: Column?
0:50:39 Kendall: Yeah. ⌈They (did another point.)
0:50:40 Tyler: ⌊Yeah because (0.4) first (0.3) we (.) wrote all the numbers out, (.) we ripped (.) it between (1.0) ahm: me and Kendall had one piece and uh =
0:50:49 Kendall: = Edith. =
0:50:49 Tyler: = Yeah tha:: girls and THEN: ha ha

0:50:52 Edith: ⌈⌈he he
0:50:52 Jasmine: ⌊⌊he he
0:50:53 Tyler: And then we marked off (0.8) ahm: ⌈which ahm me yeah which was the lowest, second, third, fourth, ⌈fifth up to the highest,
0:50:55 Kendall: ⌊°(which ones) were the lowest°
0:51:00 Edith: ⌊Um the person that helped us, we can show you, ⌈I don't know if that person brought them back (I haven't seen them)
0:51:02 Tyler: ⌊And then (1.3) and then we read them off on a on a different sheet of paper, in order (0.6) so the first would be up here the second (0.6) and keep going down
0:51:13 Kendall: °Yeah.°
0:51:13 Tyler: And then we had to say em (0.7) but (0.4) um: ⌈they might
0:51:16 Edith: ⌊Look here's the sheet
0:51:16 Edith: ⌊((*using chalk to draw the sheet with which they organized the data*))
0:51:18 Tyler: Yeah (1.1) we went like =
0:51:19 Edith: = well if it was bigger (1.9) her:e's the like four rows well there's ⌈three rows
0:51:25 Kendall: ⌊Three.
0:51:26 Edith: We read this (.) by going (1.9) like this (0.6) ⌈but
0:51:30 Tyler: ⌊Yeah (0.7) ⌈no down =
0:51:32 Tyler: ⌊((*reaches in to point at Edith's figure on board*))
0:51:32 Jasmine: = ⌈down (2.2) hehehe
0:51:32 Jasmine: ⌊((*reaches in to point at Edith's figure on board*))
0:51:35 Edith: Like that! (0.4) ⌈And then we would go through the numbers (0.5) and say like there's a number here (0.6) and that's the lowest (well) you mark that number one and then: we find the other number on the sheet (.) and then mark number two and then we keep on going, =
0:51:37 Tyler: ⌊There you go
0:51:50 Jasmine: = Yeah but that would be (0.4) this is how the girl:s did it we did it with our one two three thing (0.0) ⌈and I think the guys did a little different than we did,
0:51:54 Edith: ⌊Yeah but the boys::
0:51:57 Tyler: Blame it on us.
0:51:58 Jasmine: Huhuh
0:51:58 Kendall: Well na no (0.8) we started to do it that way but then we just like (0.8) looked for the
0:52:05 Kendall: ((*turns to look at Tyler*))
0:52:06 Tyler: °Right° (1.1) we (1.3) °what are you talkin' about?°

0:52:10	class:	HAHAHAHAHAHAHAHAHA
0:52:12	Kendall:	How did we do that?
0:52:13	Tyler:	NO:::! Yeah we sed (0.3) like we read em off: and then we >(I know)< we checked em ⌈one two three four
0:52:19	Kendall:	⌊We we ran off the ones that were in like
0:52:22	Tyler:	And then you read em to me and then I wrote em down on a big ⌈(piece)
0:52:26	Kendall:	⌊Did you write a ( )?
0:52:27	Tyler:	And then we ⌈SHARED THEM WITH THEM
0:52:28	Tyler:	⌊((*gestures with both hands toward Edith and Jasmine*))
0:52:29	Tyler:	⌈⌈((*spinning and gesturing toward Group 3 graph*))
0:52:29	Tyler:	⌊⌊And we wrote me down on the graph
0:52:31	Kendall:	Yeah.
0:52:32	(Jasmine):	What?
0:52:32	CH:	So you made a mistake.
0:52:34	teacher:	Yeah! So you guys made a mistake. (1.1) There's not- (0.3) how many hundred and tens are on this graph? (0.6) here
0:52:41	Kendall:	⌈⌈One,
0:52:41	Tyler:	⌊⌊One,
0:52:42	(Edith):	Two
0:52:42	(Jasmine):	Two
0:52:42	Kendall:	Is there one? (0.8) two
0:52:45	teacher:	Okay and how many hundred and tens do you have ⌈here?
0:52:47	teacher:	⌊((*pointing at 110s column on Group 3 graph*))
0:52:48	Tyler:	Hmm two.
0:52:49	Kendall:	Two.
0:52:50	teacher:	Okay. And then a hundred and eleven?
0:52:52	Edith:	°There's only wah:ne.°
0:52:53	Rene:	There's only ⌈one one ⌈hundred ten on that one.
0:52:53	(Kendall):	⌊Right there!
0:52:54	(Jasmine):	⌊It's on the first one.
0:52:55	Edith:	It's on the first ⌈(list there).
0:52:56	Kendall:	⌊Right there.
0:52:56	(Tyler):	We have it there,
0:52:57	Rene:	You guys!
0:52:58	Kendall:	And then a hundred and ⌈tw:elv:e. =
0:52:59	Tyler:	⌊tw:elv:e. =
0:53:00	Rene:	= You guys there's only one one hundred ten over there.
0:53:03	CH:	So Edith do you think that other graph is ri:ght? It shows what's ri:ght? And ⌈where you guys made mistakes
0:53:07	Jasmine:	⌊((*walking toward Group 2 graph*))
0:53:15	Jasmine:	So so this: (.) group should have one more one hundred ten

0:53:19 student: No::,

0:53:20 Jasmine: Yes:::::? Cuz it sez on the graph↑↑ that you should↑↑.

0:53:25 teacher: There's a hundred and ten here (0.4) and there's a hundred and ten right ⌈here.

0:53:29 Jasmine: ⌊He said there were (.) about sixty-three numbers he didn't say exactly sixty-three

0:53:32 Garrett: Yeah he did. You guys ( )

0:53:37 Jasmine: We won't we have ⌈( )

0:53:37 Wally: ⌊Tyler! Tyler!

0:53:39 (Tyler): There it is one fourteen to one one fifty

0:53:43 Tyler: What?

0:53:44 Wally: Om:: (0.4) ⌈they put (.) only one one hundred ten on their's.

0:53:45 Wally: ⌊((*points from seat toward the Group 2 graph*))

0:53:49 Jasmine: (And like) ⌈( )

0:53:50 Tyler: ⌊I know but that's wrong. (0.4) It shouldn't be like that.

0:53:52 Wally: That means like your's is wrong then.

0:53:56 Janet: Where's: one hundred ⌈fif:tee::n?

0:53:57 Tyler: ⌊Yeah we have six:ty-six.

0:54:00 Kendall: We're looking!

0:54:01 Janet: It's not up ther::e.

0:54:02 Kendall: Yeah it's right ⌈there

0:54:03 Kendall: ⌊((*pointing to item on data list*))

0:54:03 Jasmine: ⌊((*pointing to item on data list*))

0:54:03 Tyler: ⌊((*pointing to item on data list*))

0:54:04 Kendall: One fifteen,

0:54:06 Tyler: Yeah, and then one ⌈(.) one sixteen

0:54:07 Kendall: ⌊One sixteen.

0:54:08 Tyler: So we did that one right.

0:54:10 Tyler: What was the other one ⌈Michael?

0:54:11 female: ⌊Oh my gosh::!

0:54:13 Michael: No I have ( ) one hundred and ten. That was the ( ).

0:54:16 Tyler: No I mean there was another (.) line of stuff that

0:54:20 Michael: No I said (.) that um one hundred and ten means a hundred and ten was th'same on that. ⌈They're different on that.

0:54:24 Wally: ⌊Well one of ⌈those two hundred and five thingys

0:54:25 Wally: ⌊((*points from his seat at the Group 2 graph*))

0:54:27 Tyler: ⌈The two hundred ⌈one two three four five ⌈six
0:54:27 Tyler: ⌊((*counting up the 200s column on the Group 2 graph*))
0:54:30 Tyler: ⌊((*walking across front of room to his group's graph*))
0:54:31 Jasmine: Well they're ⌈the same.
0:54:33 Kendall: ⌊( ) two hundred and nine.
0:54:36 Tyler: I'm sayin' (.) oh it's right here!
0:54:37 Wally: Yeah I know cuzz there's (.) three over there and only two over there.
0:54:40 Tyler: Okay then look for two hundred.
0:54:42 Tyler: There's two oh five, two hundred
0:54:50 teacher: Okay so: basically what you guys are saying is there's some errors made on both graphs.
0:54:55 Tyler: Yup.
0:54:56 Kendall: ⌈Yeah.
0:54:56 Edith: ⌊Yeah.
0:54:56 Jasmine: ⌊Yeah.
0:54:56 teacher: Yeah?
0:54:57 Edith: I don't know ( ) we were like reading them off to each other?
0:55:02 teacher: Okay.
0:55:02 Edith: Putting them on the graph so:
0:55:04 (Kendall): >Everybody< like =
0:55:05 Edith: = I think we kinda ⌈( )
0:55:06 Jasmine: ⌊But when we read 'em off like (0.6) Kendall (0.4) would like say one and I would like say one and Tyler would say one
0:55:12 Tyler: But we might of like went off track and then went back to the same number that we weren't supposed to.
0:55:20 Jasmine: Anyone have anymore (.) questions about (0.8) ⌈( )
0:55:26 student: ⌊(They see we are)
0:55:33 Edith: ⌈Yes!
0:55:33 Edith: ⌊((*pumps hands*))
0:55:36 Tyler: ⌈Thank you. (>We're done.<)
0:55:36 Tyler: ⌊((*raises arms*))

((*Group 3 returns to their seats. Teacher consults with researchers.*))

0:55:58 teacher: Which graph up here? (1.0) or graphs:, (1.5) do people think (1.1) help show how spread out (0.5) the numbers are?
0:56:22 teacher: Kristen? (1.1) ((*specifies student's family name*))
0:56:24 Kristen: Um:: (0.5) I think the ones with the scales? (1.3) so:: ahm: >I guess< ⌈(7.2) this o:ne, (1.6) this one, (0.6) and this one? And I don't umm: I (.) I think this one has a scale. Yeah.

0:56:35	Kristen:	⌊((*Walks to the board*))
0:56:56	teacher:	Okay, Michael?
0:56:57	Michael:	Well (0.6) I:: don’t really think um: the bar graphs? (1.0) om: show us the spr:ead? (0.5) cuzz if you did have five hundred and fifty five? (0.7) on there it doesn’t look like it would be way far to the right, (0.6) (plus) five-thirty from ⌈five hundred and fifty five. (0.4) It’d just be way up? (3.4)
0:57:13	Ian	⌊It’s be way high up though.
0:57:20	Michael:	OH YEAH- NO:! (1.0) That’s how they did it.
0:57:23	teacher:	Okay. (1.0) Janet?
0:57:25	Janet:	Well: uh (1.0) what the definition of spreadout is cuzz Rene and (I said) spreadout was a little bit different than what
0:57:37	teacher:	What do you think the definite- what do you think spread means?
0:57:39	Janet:	Well: =
0:57:40	Rene	= Like how much:
0:57:41	Janet:	how many: (0.3) like numbers are between =
0:57:44	Rene:	= between (1.3) the (0.4) the lowest and the highest.
0:57:48	teacher:	Okay. Does your graph:? help you see:, (0.7) how spread out they are? >If you this look at< this these numbers?
0:57:54	Janet:	⌈Yes::.
0:57:54	Rene:	⌊Yes:.
0:57:58	student:	°No::.° ((*whispered*))
0:57:58	Janet:	⌈((*drops head onto table*))
0:57:58	student:	⌊HEhe ha ha.
0:58:01	teacher:	How how does it do that Rene?
0:58:03	Rene:	Becau⌈s::e if if you go (along like we said)
0:58:07	Rene:	⌊((*turns in chair to face the board*))
0:58:07	Rene:	((*makes vague gesture with both hands*))
0:58:08	teacher:	‘N your graph up ⌈here. (0.5) Does it help you see how (.) spread apart the numbers are?
0:58:09	teacher:	⌊((*places open palm over the Group 5 graph on the board*))
0:58:12	Rene:	Yes::. (0.4) Thir:ty? (0.6) throu:gh two hundred ’nd fifty five, it shows all: the numbers.
0:58:16	Edith:	Cuz they have ‘em ⌈underlined (0.5) like (0.3) X.
0:58:18	Edith:	⌊((*gestures toward board with index finger of left hand*))
0:58:19	teacher:	What do you think (3.5) Wally?
0:58:26	Wally:	>I don’t< (0.7) think it really does becuz: (1.6) I mean it’s:: (0.6) °can I go up?°
0:58:33	teacher:	Hm hm,

0:58:33	Wally:	((*rises from seat and proceeds to the board*))
0:58:36	Wally:	It's like om:: (4.7) it's just um: (1.6) all scrunched together and you can't real:ly (.) tell:, (0.7) it's like it's just ( ) (1.1) you can't tell if that's:: (2.2) all ⌈( )
0:58:56	teacher:	⌊How far apart- it looks like to me thirty and forty-five on this gra- >I think that's what your tryin' to say< well thirty and forty-five on this graph? (0.6) look like they're one apart.
0:59:05	Wally:	>Yeah.<
0:59:06	teacher:	Does <u>thirty</u>: and forty-five (0.6) on this graph? (0.5) help you see >whadda they, look like?< though.
0:59:13	Wally:	They're one apart (0.4) but (0.3) um: (2.1) it's (0.6) like actually (1.1) in: one of ⌈these, (.) and it goes and you see why they did it also.
0:59:22	Wally:	⌊((*points to one of the left-most columns in the Group 3 graph*))
0:59:29	Wally:	This just ⌈looks (1.9) ⌈like ⌈(2.1) altogether.
0:59:30	Wally:	⌊((*turns gaze and swings arm toward the Group 5 tabular representation*))
0:59:32	Wally:	⌊((*compresses his two hands together - repeated three times*))
0:59:33	Rene:	⌊(Same as for <u>that</u>.)
0:59:36	teacher:	>Where wou- where would< where would three hundred be on your graph, Rene? (1.1) If there was a three hundred? =
0:59:41	Wally:	= ((*points to the end of the table on the Group 5 representation*))
0:59:43	students:	Hehehe haha hehehe haha hehehe haha. =
0:59:48	teacher:	= What?
0:59:48	Rene:	Like not all the numbers in between? =
0:59:50	teacher:	>So does that help you see that it's< spread? >that there's a difference< between three hundred and two-fifty five?
0:59:56	Rene:	°No.°
0:59:57	teacher:	⌈Or not?
0:59:57	Rene:	⌊((*swings head back and forth*))
0:59:59	teacher:	Would would where would three hundred be on ⌈<u>this</u> graph? (.) would you say?
1:00:01	teacher:	⌊((*gestures toward Group 3 graph*))
1:00:02	Rene:	⌈No, actually yes it would.
1:00:02	Rene:	⌊((*stretches hand up urgently*))
1:00:04	teacher:	Okay, how?
1:00:05	Rene:	Becuz: (0.3) according to the way me and Janet do it, (0.7) okay. There's three hundred, just if there's those two numbers? (0.8) how much

		apart are they? (0.3) It's easy. Okay. (0.4) If you start on two-fifty five and then you add three hundred, (0.5) you just minus two fifty-five from three hundred.
1:00:25	teacher:	Right but would your graph show that? Cuz you have three hundred right ⌈here >two fifty-five< right ⌈here, would that show ⌈how spread it is? =
1:00:27	teacher:	⌊((*pointing to place where 300 would appear in Group 5 table*))
1:00:28	teacher:	⌊((*pointing to 255 in the table))*
1:00:30	teacher:	⌊((*performs pinching gesture with thumb and index finger))*
1:00:30	teacher:	= Or would you have to do some math to figure it out?
1:00:32	Rene:	You would have to do just a little math.
1:00:34	teacher:	Okay. Well what about ⌈this graph? =
1:00:34	teacher:	⌊((*points to Group 3 graph*))
1:00:35	teacher:	= Would three hundred be right ⌈here or would three hundred whusst be (.) out ⌈here further?
1:00:37	teacher:	⌊((*points next to 255 on Group 3 graph))*
1:00:39	teacher:	⌊((*points off beyond right border of Group 3 graph))*
1:00:41	Rene:	°Further.°
1:00:42	teacher:	Okay. So would that graph help you chu- would that would ⌈this graph (0.5) show you (.) better? (0.6) Just the graph. (1.1) How spread out it is?
1:00:44	teacher:	⌊((*points toward Group 3 graph*))
1:00:56	Rene:	°Yes.°

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