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The Comparative Understanding of School Subjects:

Past, Present, and Future

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Abstract

Research in education has elevated the proposition of knowledge's domain-specificity from a working hypothesis to a *de facto* truth. The assumption of domain-specificity structures handbooks of research, organizes branches of funding agencies, and provides subject headings for conference proceedings. It shapes the contours of graduate training and teacher education programs. Correspondingly, leading scholars of teaching and learning often focus on a single slice of the school day (e.g., math, language arts, science, or history), despite the possibility that these segments swirl into an undifferentiated blur for children, especially during the elementary school years. In this respect, there may be a pronounced misalignment between researchers' monocular focus and children's phenomenological experience. In this article we examine the current domain-specific landscape, beginning with the not-so-distant past, when domain-generality, not domain-specificity, reigned supreme. We then examine the transition from domain-general to domain-specific approaches, describing along the way key developments and contributors. Next, we offer an alternative to a domain-general or domain-specific stance, a position we call the *comparative understanding of school subjects*. At its core, a comparative understanding trains attention on how the same children understand multiple subjects in a given school day. We argue that this approach represents a promising path for conceptualizing research on children, schooling, and thinking by raising questions about children's understandings that have hitherto gone unasked. We conclude by proposing a research agenda that would embody and advance a comparative understanding of school subjects.

A Comparative Understanding of School Subjects: Past, Present, and Future

It is mid-morning as Melissa, a fifth-grader, sits at her desk waiting for science to begin. Today, Melissa's class will examine fast-sprouting plants and discuss what causes their growth. Later, students will conduct experiments and present evidence for why some plants flourished and others died. After lunch, the focus will turn from science to social studies. Students will read the chapter in their textbook about the causes of the Civil War. To scaffold their reading, Melissa's teacher will distribute a worksheet that lists the causes of the Civil War and instructions on how to support each cause with evidence.

At the end of the day, a fairly typical one for Melissa, she approaches her teacher and asks a deceptively simple question: "When we worked with plants, you asked us to think about *causes* and *evidence*. You asked the same thing when we read about the Civil War. Do these words mean the same thing in science and social studies?"

How should a teacher respond to this precocious (and imaginary!) fifth-grader's questions? Furthermore, if teachers look for guidance in the educational research literature, what might they find? In what ways, precisely, *are* science and history similar? In what ways are they different? Perhaps the question is framed incorrectly, for there is no such thing as history with a capital H or science with a capital S. Which *forms* of science and history might be closer to one another, and which might be farther apart? How would we even begin to make judgments about disciplinary compatibility and coordination?

Our principal claim is that the field of educational research has little to say in response. At present, neither Melissa's teacher nor the great majority of scholars involved in educational research are able to offer much in terms of counsel, and even less in terms of materials for engaging questions of comparative disciplinarity.

To be sure, attempts to integrate disciplines have been a mainstay of the educational landscape, and have a long and hoary history (Adler & Flihan, 1997; Becher, 1989; Capehart, 1958; Henry, 1958; Klein, 1990). Indeed, the attempt to integrate subjects (especially English and history) was a core feature of the famous Eight-Year Study (Aiken, 1942). As recently as 1994, a survey of over ten thousand schools found that nearly two-thirds had already implemented or were planning to implement interdisciplinary curricula (Cawelti, 1994). The interdisciplinary phenomenon extends far beyond American borders. To cite one example, the Canadian province of British Columbia's blueprint for school renewal, *British Columbia Year 2000*, placed "curriculum integration" at the top of its reform agenda (Case, 1994).

One of the best-known calls to create interdisciplinary curricula is the "how-to" approach advocated in Stephen Tchudi and Stephen Lafer's (1996) widely used textbook, *The Interdisciplinary Teacher's Handbook: Integrating Across the Curriculum*. The authors base their advice to teachers on a series of distinctions between "traditional instruction" and the approach they support: "interdisciplinarity." Interdisciplinarity, they argue, offers a fresh alternative to the "stranglehold of disciplinary knowledge," which serves up to students "canonical" and "standard" knowledge. By contrast, interdisciplinarity offers a curriculum of "constructed knowledge" pursued by engaged

students working “in the service of inquiry” (Tchudi, 1994; Tchudi & Lafer, 1996; cf. Beane, 1995).

The problem with such characterizations (besides their romanticized images and either/or thinking) is that advocacy tends to supersede descriptions of what actually happens when such curricula are implemented. Despite the popularity of interdisciplinary approaches, there is no body of evidence that attests to greater learning in high-quality interdisciplinary classrooms versus high-quality disciplinary classrooms. A likely place to look for work that speaks to these questions is in the literature surrounding Sizer's Coalition of Essential Schools, a movement that grew out of the Study of High Schools and Sizer's (1992) calls for reform in *Horace's Compromise*. Coalition principles eschew narrow disciplinarity, and call for teachers to see themselves as generalists first and disciplinary specialists second, with the overarching goal of teaching students to "use their minds well." However, to date research on Coalition outcomes has focused almost exclusively on issues of implementation and teachers' response to school change, with little attention paid to changes in student learning, changes in student understanding of "essential knowledge," or gains in student achievement (cf. Husbands & Beese, 2001; Muncey & McQuillan, 1996). Nor has the study of students' comparative understanding of subject matters been broached in the evaluation literature on Coalition schools.

The problem goes beyond the absence of student achievement data. The existing literature on interdisciplinarity is almost entirely prescriptive (of programs, of theoretical approaches, of teacher lesson plans) and almost entirely devoid of descriptions of learning that occurs (or doesn't) when theory meets practice (Adler & Flihan, 1997;

Wineburg & Grossman, 2000). Little is known about what happens when integrated curricula, hatched in well-funded educational hothouses, are let loose across sprawling urban districts with competing interests and educational traditions (for exceptions, see Hammerness & Moffett, 2000; Muncey & McQuillan, 1996). Even less is known about how children across different grade levels and subject areas make sense of their teachers' attempts to merge different subjects and curricula (cf. Rényi, 2000, Roth, 2000). Indeed, as Boix-Mansilla and Gardner (1994) note, most of the school curricula produced under the interdisciplinary banner are better characterized as *pre-* rather than *inter-* disciplinary, because they rarely draw on features of disciplines that lead to conceptual and practical advances in knowledge. Typically such curricula link at the topical, not disciplinary, level, ignoring altogether how disciplinary traditions verify and judge competing knowledge claims (Roth, 2000).

Despite the presence of multiple subjects in the school day, questions of comparative disciplinarity are hardly ever discussed with schoolchildren. What tends to happen instead is that students are left to forge connections from one subject to the next: The Melissas of the world are left to their own devices. In other words, those least equipped to bring conceptual order to the school day—students themselves—end up shouldering the burden of having to do so. If scholars are daunted by the task of articulating the similarities and differences between disciplinary worlds (cf. Messer-Davidow, Shumway, & Sylvan, 1993), how bewildering this maze must be for children, whose day skips seemingly without rhyme or reason from one subject to the next. To an elementary schoolchild, as Judith Rényi (2000) has wryly observed, a typical school day

makes as much sense as “First we do reading, then we do math, and then we do lunch” (p. 41).

The problem addressed in this article is one we call the *comparative understanding of school subjects*, or how the same students in the same class make sense of the temporal segments that comprise the school day. Few active research programs explicitly focus on how children construe a day shaped by the school-based variants of the academic disciplines.¹ Research programs on teaching and learning typically carve up the day into fixed portions—mathematics, science, social studies, or literacy—and study them in isolation. Indeed, the working assumption of domain-specificity orders the field of teaching and learning, providing it with chapter headings for handbooks, subject sections for conference proceedings, even organizing branches at funding agencies.

The widely disseminated *How People Learn: Brain, Mind, Experience, and School* (Bransford, Brown, & Cocking, 1999), a report commissioned by the National Research Council, provided a scientific seal of approval for this domain-specific map. Written by leading scholars of teaching and learning, *How People Learn* called for increasing research dollars for “discipline-specific research on the level and type of education required for teaching that discipline in elementary, middle, and high school” (p. 267). Nowhere did the report offer any hint that teachers who teach multiple subjects might need to know something about how disciplines interrelate or that different disciplines provide alternative versions of establishing truth. More by omission than anything else, this report seemed to suggest that effective teachers need only the additive knowledge of how to teach each discipline in the curriculum separately.

In this article, we provide a context for understanding the present landscape and offer an alternative way of conducting research on teaching and learning. We begin by stepping back and offering an encapsulated account of how the field of learning and teaching went from being dominated by general processes of memory, attention, and recall, to the present ascendance of domain-specific approaches.² Our goal here is to capture the proverbial forest, preferring to chart a few of the shifts in the field that have reverberated for decades rather than record every development in every research area. In portraying such shifts, we focus by necessity on a short list of key figures—names like Jerome Bruner, Robert Glaser, Robert Gagné, Lee Shulman, and others, who in their positions as trendsetters and spokespeople (three of these served as president of AERA) used their prestige to influence many others. To the extent that we touch on other literatures, it is in the service of illuminating our narrative rather than aiming for synoptic or inclusive reach. We adopt here an approach that appeals to what Bruner (1986) called “narrative consciousness,” where issues of verisimilitude and reasonableness form the primary desiderata for constructing a coherent narrative. In brief, our selection criteria are hermeneutic as opposed to algorithmic, appealing to narrative aesthetics (i.e., coherence, felicity, and temporal order; cf. Mink, 1966) rather than preset criteria of effect sizes, sanctioned research designs, or approved publication outlets.

In the second part of this article, we unfurl our vision of what a comparative approach to subject matter cognition might look like in practice, offering our own research program as a concrete instantiation of it. We then explain why we think this approach represents a promising line of research on children, schooling, and thinking

across the elementary school curriculum. We end by describing a research agenda that would embody and advance a comparative understanding of school subjects.

The Recent Past

Only a few decades ago, domain-generalism, especially in its behaviorist guise, was the order of the day. How, then, did things change so quickly? According to one popular account, everything in the field of teaching and learning changed as a result of the cognitive revolution and its attendant spotlight on the processes of thinking and reasoning. But history is always more complicated than any unadorned storyline, for change *and* continuity characterize the relationship between past and present. As we shall see in the careers of two prominent educational researchers, Robert Gagné and Robert Glaser, the movement from behaviorism to cognitivism was often smoother than one might imagine.³ But we are getting ahead of ourselves, so first a word about behaviorism.

Behaviorists cared little for domain-specificity. Sweeping in its reach, behaviorism, deploying a vocabulary of shaping, reinforcement, contingency, could nimbly explain how to learn everything from riding a bicycle to writing a sonnet. When B. F. Skinner (1954) took up the question of school learning in his *Harvard Educational Review* article "The Science of Learning and the Art of Teaching," there seemed no limit to the behaviorist's horizon. Stating his creed in eminently quotable sentences, Skinner declared that any domain could be thought of in exactly the same way: "The whole process of becoming competent in any field must be divided into a very large number of very small steps, and reinforcement must be contingent upon the accomplishment of each step" (p. 94). Not only did this principle apply to the dizzying variety of human endeavors (Skinner focused on mathematics in his article), but it extended beyond the

human species. For Skinner, differences between people and animals were differences in scale, not kind: “In spite of great phylogenetic differences . . . organisms show amazingly similar properties of the learning process” (p. 94). Without skipping a beat Skinner juxtaposed results from research with pigeons, rats, dogs, monkeys, “human children,” and “human psychotic subjects” (p. 89). The point was unmistakable: Variations in the form of learning or its agents paled in comparison to the fundamental unity of learning itself.

Did the cognitive revolution alter this monolithic orientation toward learning, shaking a mighty foundation and sundering it into so many domain-specific parts? Not initially—or so argued Jerome Bruner (1990) in *Acts of Meaning*. Rather than a “revolution” (a movement characterized by a breakdown of structures and systems), Bruner saw a neat symmetry in the general architecture of behaviorism and the brand of cognitivism that came to dominate; switching from one system to the other, he argued, required a trip to the haberdasher rather than the reconstructive surgeon. Bruner, however, offered little evidence for this assertion other than a general formulation of the claim.

If Bruner was right, we should be able to see this shift (and its attendant intellectual effects) played out in the life histories of individual scholars. Did researchers change their way of viewing learning as they shed behaviorism in order to adopt cognitivism, or did they adopt a new vocabulary, only to leave many of their fundamental assumptions intact? In the following section we examine this question by charting the different journeys taken from behaviorism to cognitivism by two of the most influential scholars in the history of modern learning theory, Robert Gagné and Robert Glaser.

Behaviorism to Cognitivism: Two Masters.

Robert Gagné's classic *The Conditions of Learning* (1965) was a compact treatise that wedded general learning theory to instructional design. The opening section, a review of Thorndike, Skinner, and Hull, provided the reader with a primer on stimulus response terminology, a useful albeit familiar synthesis across competing behaviorist systems and vocabularies. Where Gagné innovated, however, was in melding these systems into one all-embracing taxonomy that classified every form of learning, from the most basic to the most sublime.

What made the system particularly useful for educators was that it applied not to rats or paired-associates but actual pieces of content in the school curriculum. With the tool of task analysis, what appeared at first blush to be a complex understanding of conceptual information in science turned out to be a linear progression of prerequisite skills. So, for example, a pupil's understanding that "gases expand when heated" did not constitute a conceptual breakthrough, but rather "a chain of two or more concepts" strung together in a way that hid its origin in "previously learned facts" (Gagné, p. 51).

Well and good for science, at least in how that subject was conceptualized by many in the early 1960s. But what about literacy? For Gagné, language learning, like science, depended on carefully sequenced activities that built on each other until they reached heights of competence. This learning process (when it went well) followed predictable vertical trajectories: "It is now generally conceded that only when early skills are mastered is the student ready to progress to later stages of language learning" (Gagné, p. 190).

What were teachers to learn from the disaggregation of school tasks into constituent parts? One message was that while separate subject-specific textbooks, curricula, or even methods courses in teacher training might guide the social organization of education, such labels clouded the underlying structure of learning. More dangerously, these labels could lead teachers astray by obscuring the fundamental unity of learning itself.

Nine years after Gagné published *Conditions of Learning*, much had changed in the field of learning and teaching. By the time he wrote *Essentials of Learning for Instruction* (1974), a short paperback expressly for teachers and widely adopted in teacher education programs, gone were the diagrams of stimulus-response bonds and the scare quotes that quarantined the word “idea.” Instead came a new cognitive armamentarium of “effectors and receptors,” “executive control systems,” and diagrams of the memory system linking short- and long-term memory.

Unchanged, however, was Gagné’s boundless taxonomic impulse. He now offered a model of the “eight stages of instruction” that could guide teachers, whether they taught students to compute the area of a rectangle or master the provisions of the First Amendment (p. 118). As in previous formulations, the skilled teacher was one who could see beyond the illusory labels of science, math, and history in order to discern the deep structures of learning, and to ply the skills of the (now cognitive) instructional designer. As Gagné would write two years later in the yearbook of the National Society for the Study of Education (NSSE), “There is no sound rational basis for such entities as ‘mathematics learning,’ ‘science learning,’ ‘language learning,’ or ‘history learning,’ except as divisions of time devoted to these subjects during a school day or term” (1976).

In the person of Robert Gagné, one of the leading figures in learning research during the previous half-century, the cognitive revolution did little to alter a deep and abiding commitment to the domain generality of teaching and learning.

Robert Glaser's career offers a different perspective on the transition from behaviorism to cognitivism. For years Glaser was the director of the Learning Research and Development Center (LRDC) at the University of Pittsburgh, and one of the preeminent researchers on learning. In the mid-1960s, LRDC became one of the original federal laboratories on learning, and achieved national prominence as an R&D center, conducting basic research on learning as well as producing innovative school curricula. During the early 1960s, there were few fundamental differences between Glaser's approach to school learning and Gagné's. For example, Glaser worked on translating behaviorist theory into programmed instruction materials for the teaching of mathematics (Taber, Glaser, & Schaefer, 1965), drawing on task analytic approaches reminiscent of Gagné's hierarchies of skill.

However, as the cognitive star rose, Glaser followed its trajectory, adopting in his writings the general cognitive frameworks of his crosstown colleagues Herbert Simon and Allen Newell (Newell & Simon, 1972). But other changes were afoot. By 1981, it was possible to discern in Glaser's writings the footprints that would lead away from a domain-general position toward a domain-specific stance. In his presidential address to Division 5 (Evaluation and Measurement) of the American Psychological Association, Glaser (1982) outlined the promising developments in the field, practically all of which took the form of different domains: Brown and Burton's (1978) work on arithmetic

“bugs,” Shaughnessy’s (1977) study of writing errors, and Chase and Simon’s (1973) work on expertise in chess.

Glaser’s own empirical program gave further impetus to the domain-specific push. With colleagues Paul Feltovich and Michelene Chi, Glaser turned his attention to problem-solving in physics. In their seminal research report, Chi, Feltovich, and Glaser (1981) employed the language of knowledge representations, disciplinary structure, and problem-solving templates in their analysis of how people with varying degrees of knowledge discern, classify, and solve problems taken from a college physics textbook.

Three years later Glaser’s status as a major flag-bearer for the centrality of domain-specific learning was virtually complete. In his E. L. Thorndike Address to Division 15 (Educational Psychology) of the American Psychological Association, Glaser (1984) reviewed the leading thinking programs of the day: Covington, Crutchfield, Davies, and Olton’s *Productive Thinking Program* (1974); the CoRT program of British psychologist Edward de Bono (1985); Matthew Lipman’s *Philosophy for Children* (1977); and Whimbey and Lockhead’s *Solving and Comprehension: A Short Course in Analytical Reasoning* (1980). By focusing on general reasoning skills, abstract decontextualized problems, and knowledge-lean problems, these programs, according to Glaser, dodged the “complexity of subject matter information” (p. 96). The result, he argued, was a mismatch between general thinking programs and the kinds of learning students did in school. Despite his early advocacy of flexible, domain-general modes of thought, Glaser had now emerged as one of the chief critics of “knowledge-lean” approaches to cognition:

The programs that I have described are based on early theories of human cognition. . . . Others derive from early information-processing theory that explored knowledge-lean problems. . . . When faced with such novel situations [people] resort to general methods. But in the context of acquired knowledge and specific task structures, these methods may be less powerful . . . [General cognitive research] as such offered limited insight into learning and thinking that require domain-specific knowledge (pp. 96–97).

This was a biting indictment to issue before an audience of educational psychologists, many of whom had made careers out of articulating general problem-solving strategies. Thus, in the career of Robert Glaser we see a different embodiment of intellectual history. Unlike Gagné's, Glaser's conversion to cognitivism ultimately led him to the conclusion that thinking in school subjects was inextricably tied to the specific, and that differences in disciplinary knowledge were central to intellectual life.

Domain-Specificity Ascendant

What did these seemingly major changes in research epistemology mean for how the learning psychologist did his or her work? In an earlier age, the learning specialist could erase subject-matter differences because of a widely-held belief in the applicability of general thinking and learning processes. But now that thinking came packaged in so many variations, which were characterized by deep and complex differences, what was a harried researcher to do? For the first time in the history of learning research, questions could be raised about which training was most needed by someone who wanted to study learning: was it general theories (and corresponding research methods), or detailed and

specific knowledge in the domain (e.g., math, biology, physics) of interest? Or some combination of both?

Irrespective of the answer, by the late seventies a different kind of person had entered the portals of learning research. Two of these newcomers were Andrea diSessa, a physicist, and Alan Schoenfeld, a mathematician, today two of the leading theorists on learning and teaching in their respective subject areas. DiSessa, who collaborated with Seymour Papert on early Logo work, made his mark with a widely-cited paper, “Unlearning Aristotelian Physics: A Study in Knowledge-Based Learning” (1982), which showed the persistence of undergraduates’ beliefs before and after an introductory physics course at the Massachusetts Institute of Technology. Schoenfeld, who conducted research on mathematical problem-solving while teaching calculus to undergraduates at Hamilton College in Clinton, New York, brought together a volume of his papers in *Mathematical Problem Solving* (1985) that, for many, served as a research agenda for mathematics education during the following decade.

It would be misleading, however, to portray the emergence of domain-specificity (and the new kinds of researchers it attracted) as a development of the 1980s, something that followed in the wake of the turn to cognitivism. In actuality, ideas about the specific features and entailments of knowledge had circulated among educational researchers at least since the late 1950s and early 1960s. Arguably the most influential work about education during the 1960s was unabashedly domain-specific in orientation. Jerome Bruner’s *Process of Education* appeared in 1960, and its ideas about disciplinary structure left their mark on major curriculum projects such as *Man: A Course of Study* (Bruner, 1966, cf. Dow, 1991) and *Harvard Project Physics* (Bruner, 1983). Bruner

(1960) drew explicit attention to the fundamental ways of knowing in the academic disciplines (e.g., notions of tropism in biology, plot in literature, proof in mathematics, the counter-factual in history) that often got tossed by the wayside when disciplines migrated from the academy to the school. Similar (but not identical) in formulation were the ideas of University of Chicago geneticist and curriculum theorist Joseph Schwab. Schwab, whose influence was also directly felt by curriculum reformers (e.g., Biological Sciences Curriculum Study, BSCS), claimed that each of the major disciplines possessed a “syntax,” a distinctive means of verifying and justifying knowledge claims, in addition to its own body of “substantive” content (Schwab, 1978).

Across the Atlantic, attention to disciplinary knowledge had its counterpart in the writings of Paul Hirst, who argued that disciplines were more than groupings of related topics, but constituted fundamentally different ways of knowing. In Hirst’s (1973) formulation, academic disciplines exhibited four characteristics: (a) a body of concepts and key ideas—a common vocabulary; (b) distinctive ways of relating these concepts and ideas; (c) characteristic ways of establishing a warrant for truth claims, such as the psychologist’s appeal to the laboratory or the historian’s to the documentary record; and (d) distinctive forms of inquiry, such as the chemist’s use of X-ray spectroscopy or the physicist’s use of a linear accelerator. Together, Hirst’s and Bruner’s ideas provided the intellectual firmament for the largest and most successful reform of history education in any English-speaking country—the School’s Council History Project (Shemilt, 1980; cf. Wineburg, 2001). At its zenith, the School’s Council Project, a non-chronological approach to history teaching that emphasized the use of primary sources and historical thinking, found its way into a quarter of schools in the United Kingdom (Rosenzweig &

Weinland, 1986) and left an indelible mark on that country's national curriculum (Booth, 1994).

Among researchers who focused on teaching, Lee Shulman trumpeted the domain-specific call most loudly. Shulman's call to arms was a chapter in the 1986 *Handbook of Research on Teaching*, with its provocative subhead: "The Missing Paradigm in Research on Teaching." Shulman argued that research on teaching had focused on the wrong targets—teachers' personality characteristics, generic pedagogical behaviors, favored management procedures—everything, it seemed, except how teachers thought about the content of instruction. In his words, research on teaching had "fallen short . . . in the elucidation of teachers' cognitive understanding of subject matter content and the relationship between such understanding and the instruction teachers provide for students" (p. 25). Shulman allied his budding program of research on teaching with the ascendant star of domain-specific work on learning:

The thrust of the cognitive research program in learning is subject matter specific rather than generic. That is, the schemata used to make sense of instruction on photosynthesis in a biology class are completely different from those used to understand the concept of inertia in physics. . . . Most of the cognitive research on teaching has ignored the teacher's cognitive processes in this sense. There have been no studies of teachers' knowledge, of the schemata or frames they employ to appreciate student understandings or misconceptions. (p. 25)

Like his University of Chicago mentor, Joseph Schwab, Shulman contended that at the heart of instruction were the core ideas of the disciplines embedded in school

subjects. In order to teach the school curriculum, teachers' generic knowledge could take them only so far. What teachers most needed to promote students' intellectual development was *pedagogical content knowledge*, a form of knowledge that was "the unique province of teachers" (Shulman, 1987).

From its inception, pedagogical content knowledge was tied to deep understanding of the subject matter of instruction (Grossman, 1990; Wilson, 2001; Wineburg & Wilson, 1988). It was a form of knowledge that enabled teachers to take their understanding of content, and transform it into representations that would usher in new learning: how to help students understand a participatory democracy in which the vote for the executive is indirect; how to anticipate students' beliefs about the movement of physical objects when teaching the counterintuitive principles of force; how to explain the procedure of "invert and multiply" so that students came to understand the reciprocal relationship between multiplication and division, rather than committing to memory a brittle recipe. Pedagogical content knowledge directly challenged the notion that a good teacher could teach anything. According to Shulman's formulation, a social studies teacher who believes that the history textbook *is* history cannot engage students in legitimate historical inquiry, no matter how qualified he or she might be in classroom management or generic questioning skills.

If disciplines were truly distinctive, what did this mean for a curriculum characterized by a farrago of subjects and topics? How should researchers, not to mention teachers and administrators, think about the salad bowl of subjects that made up the school day? An essay that promised a comparative look at the variegated school curriculum appeared in the 1996 edition of the *Handbook of Educational Psychology*,

written by Shulman and his colleague, Kathleen Quinlan. After a magisterial tour through the writings of Edward L. Thorndike, John Dewey, and Charles Hubbard Judd, the authors trained their gaze on the contemporary research scene. They drew lines of comparison across four research programs in teaching and learning: Gaea Leinhardt's, Sam Wineburg's, Magdalene Lampert's, and Deborah Ball's.

Thus, while Leinhardt's (1993) work looked to exemplary forms of expert practice as judged by prevailing notions of mathematical achievement, Lampert's (1990) began with a normative stance of what the discipline of mathematics ought to look like, anchoring her claims in the philosophical and mathematical writings of Lakatos (1978), Polya (1981), and others. Likewise, Wineburg (1991a; cf. 1998) began with normative commitments about historical epistemology, but put them to test by examining the protocols of professional historians reading primary source documents. Ball's (1988, 1993) point of departure was her own teaching practice—informed by normative commitments but shaped as well by her elementary students' questions, confusions, and insights.

In practice Shulman and Quinlan's (1996) comparative understanding was a thought experiment that juxtaposed descriptions of different research programs rather than comparing the enactment of subjects *in vivo*. There was no attempt to speculate on how students who were enrolled in a math class *a la* Ball might respond to history instruction conducted in the spirit of Wineburg's critical historians. In other words, how might youngsters who had come to understand mathematics as a logical system with an agreed-upon set of ground rules understand proof and refutation in history, which abjures axioms to explain a real, not an imagined, world? If psychology is the study of individual

minds, then a comparative understanding of school subjects would seek to resolve how these minds make sense of at least two subjects. In actual practice, however, Shulman and Quinlan's essay was less a comparative look than an exercise in "parallel play" (Lee Shulman, personal communication, May 19, 1999).

The only study cited by Shulman and Quinlan that compared school subjects directly was Susan Stodolsky's research on elementary teachers' variations across the school day. In a series of research reports that culminated in *The Subject Matters* (1988), Stodolsky showed a dramatic difference in how the same teachers modified their practices depending on the subject-matter portions of the day. For example, the time devoted to math meant frontal instruction, linear progress through the curriculum, and regimented individual homework. Social studies, on the other hand, wore a looser belt. There, group projects, individual initiative, and creative departures from the textbook characterized instruction. Drawing on Paul Gump's (1967) notion of "activity structures," Stodolsky showed how different sociological arrangements in the classroom varied systematically by subject matter. However, questions that might concern a comparative understanding (how, for example, did children understand on a conceptual level the relationship between math and social studies, or compare an "argument" across subjects) were not addressed.

One of the strongest statements for domain-specificity came in a review that appeared in this journal by LRDC researcher Gaea Leinhardt and her colleagues (Leinhardt, Zaslavsky, & Stein, 1990). These scholars explicitly addressed the relationship between domain-specific approaches and the greater field of teaching and learning. Their introduction read:

This paper is a review of research and theory related to teaching and learning in a particular subject, mathematics; in a particular domain, functions, graphs, and graphing; at a particular age, 9-14. Major reviews in education are so rarely embedded. Indeed, since 1970, there has been no subject topic-specific review in the *Review of Educational Research*. Recent theoretical thinking and research in cognitive psychology, cognitive anthropology, educational psychology, and philosophy, however, suggest that there are aspects of learning and teaching specific content that are unique to or more salient to the particular topic than to the field of teaching and learning as a whole (pp. 1–2).

More than thirteen years have passed since these words were written, and the field has changed dramatically in the interim.⁴ Similar domain- and topic-specific reviews are now common and need no special introduction. Indeed, today's reviews are often more narrowly focused, such as how social studies students read textbooks in history classrooms (Paxton, 1999) or how science teachers navigate the challenges of constructivist classrooms (Windschitl, 2002). Domain-specificity, at least as a concept that structures research practice, can now be called “normal science” in the Kuhnian sense: an intellectual matrix that shapes research programs and is rarely brought to the surface for examination (Kuhn, 1962).

The taken-for-granted nature of domain-specificity is seen most pointedly in the debates between the cognitive and situated camps of learning researchers, exemplified in the spirited exchanges between John Anderson and James Greeno (Anderson, Reder, & Simon, 1996, 1997; Greeno, 1997). Drawing on their respective research programs (e.g., Anderson's work on computer tutors in algebra and geometry; Greeno's on discourse

practices in middle-school math classes), there seems to be little common ground between these poles. But this is where a debate over learning theory masks deeper structural similarities in the conduct of educational research.

Both Anderson and Greeno are fundamentally concerned with learning; both seek to understand how learning transpires in institutions called schools. But what *is* school, when refracted through the prisms of these two different research programs? It is here that we see their fundamental unity. To Anderson and colleagues, school becomes the 50-minute period devoted to algebra or geometry. To Greeno and his colleagues (1998), the time segment may be a bit longer (these researchers locate their work in middle school, and that venue often has blocked periods). But in both research programs, "school" is defined by the apportionment of time that fits the researcher's predetermined gaze. How notions of proof in geometry may affect students' notions of "proving" Macbeth's depravity are beyond Anderson's scope, just as questions of how mathematical discourse may shape poetic or historical discourse are beyond Greeno's. In both research programs, the school day—in its broad temporal contours—looks pretty much the same. Its texture is determined not by students' daily experience, but by the subject-specific gaze of the research team.

In accounting for the subject-specific organization of the field, we would be remiss to cast its character as a direct consequence of particular thinkers and their ideas. Research follows funding, and since the 1960s the biggest funder of educational research has been the National Science Foundation (NSF). But the NSF, by temperament and policy (partly as an outgrowth of the controversy over the NSF-funded *Man: A Course of Study*, see Dow, 1991) has largely restricted its K–12 portfolio to two subjects: math and

science. One unintended consequence of this pattern has been the cultivation of researchers who conceive of a school day in which subjects (both conceptually and in practice) dwell in isolation.

It remains an open question whether schoolchildren experience the different subjects in the school curriculum as truly different, or whether, once within school walls, these subjects shed their distinctiveness and become experienced as undifferentiated blurs (Brown, Duguid, & Collins, 1989; Palincsar, 1989; Wineburg, 1989). Even allowing for epistemological differences among the disciplines in the school curriculum, it is not clear how these differences are understood by students and how teachers might draw on such differences to sharpen young people's epistemological sophistication. What would a school curriculum look like in which disciplines were compared not at the topical level (e.g., the role of plants in biology and history, cf. Roth, 2000), but in terms of how knowledge is made, justified, and verified?

In the following sections we examine what a comparative approach to studying school learning might look. We do so by drawing on our own experiences in trying to implement such a program. We argue that a comparative approach generates questions about children's experiences that have hitherto gone unasked, and we conclude by laying out a set of topics that would constitute a comparative research agenda on school learning.

Toward a Comparative Understanding of School Subjects

Up to this point, our review has focused on the shift from domain-general to domain-specific approaches to school learning. In this section we propose a subsequent shift in the study of school learning, from a fragmented collection of domain-specific

accounts of school subjects to a comparative and unified one. We explain the basis for this proposed shift, explore the range of ways that such a program might be pursued, and exemplify one approach that we have pursued, in order to begin to develop a comparative understanding of school subjects.

We begin by recognizing that contemporary subject-specific research in classrooms is dominated by a basic constructivist goal—to document *students' understandings* of particular subject-specific topics, concepts, and practices.⁵ This description characterizes many different lines of contemporary work (e.g., Carpenter, Fennema, Franke, Empson, & Levi, 1991; Cobb, Wood, & Yackel, 1991; Grossman, 1990; Lehrer, Jacobson, Kemeny, & Strom, 1999). If we trace the original insight to Piaget, the leading intuition was in large part a phenomenological one. Piaget wanted to understand conceptual phenomena that at least since Kant were viewed as basic to human experience (time, space, quantity, etc.) *from a child's perspective*. Tracing a line from Piaget's work to contemporary subject-specific research shows many differences and transformations, but for our purposes what remains constant is most relevant—the focus on how adult-identified concepts are understood and develop among children, a basic focus shared by Vygotsky as well (1962).

Our argument for a shift to a comparative approach to school subject research also has a phenomenological basis, though a different, institutionally-contextualized one. In our view, the subject-specific tradition has brought greater specificity to research on learning by focusing on the details of what and how children learn within these subjects. In pursuing this sense of specificity, however, subject matter research has overlooked another sense of specificity that may organize children's understandings of school

subjects—their embeddedness in the context of a whole school day, in which subjects come and go quickly, sequenced one after the other.

We are not arguing that subject-specific research has entirely ignored the organizational context of school on students' understanding of the subjects. It is certainly a leitmotif of discipline-specific research to argue that the durable practices of “doing school” (Tyack & Tobin, 1994; cf. Pope, 2003) obstructively mediate students' experience with valued epistemic disciplinary practices (e.g., Schoenfeld, 1988; Wineburg, 1991b). These moves, however, are only partial ones in the comparative direction we are proposing, for two reasons. First, these studies strongly maintain a taken-for-granted boundary around single subjects. Second, these analyses are typically so tightly focused on students' acquisition and display of disciplinary knowledge (or lack thereof) that comparative connections to other contexts—such as other subjects or outside-of-school practices—are not explored *in the analysis of classroom activity*. In short, analysts' disciplinary and educational concerns dominate, leaving the other understandings that might be displayed by students in the same context underrepresented (Macbeth, 2002; Stevens, 2000b). Looking to the origins of constructivist views, one can see this “adultocentric” (Bauman, 1982) tension present from the beginning in both Piaget's and Vygotsky's formulations of constructivism.

What we are asking can be framed in part as a set of basic ethnographic questions—are the boundaries between subjects that are so real for researchers also real for students? Do students develop discipline-specific understandings, comparative understandings, or blurred understandings of the subjects in the context of the school? Befitting a basic ethnographic question, one body of research that might provide an

account of students' comparative epistemic understandings across the school day is found in the ethnographic literature on student experience. After all, it is among ethnography's distinctive virtues to attend to participants' sense of their experience while also relating these to the social and practical organizational conditions in which such experience is embedded.

There are several important categories of ethnographically-based work on students in schools to consider. One category of work is distinctly microethnographic, and has documented a common classroom order of practical and discursive activity for students and teachers beneath the official goals of developing subject-matter knowledge. What this line of research displays is a largely subject-general organization of public discourse and interaction in K–12 classroom life (e.g., Cazden, 1986, 1988; Macbeth, 1992, 2002; McDermott, 1976; Mehan, 1985). Another category of school-based ethnography looks outside the classroom but within the school day for its phenomena, most notably amidst those children's activities that are unregulated by adults (e.g., Devine, 1996; Eckert, 1989; Eder, Evans, & Parker, 1995; Grant & Sleeter, 1996; Thorne, 1993). Still another important category of ethnographic work has broadly compared children's in-school experiences with their experiences outside of school (e.g., Heath, 1982, 1983; Gregory, Long, & Volk, 2004; Philips, 1983). Finally, ethnographic research from anthropology, sociology, and educational psychology has focused on the general structural tensions between students and the official agendas of their schools (e.g., Becker, 1972; Jackson, 1968; Rist, 1973; Willis, 1977). This tradition has led to such important ideas as hidden curricula, resistance, and school as a site for the reproduction of society (cf. Yon, 2003). Despite the extent of ethnographic research on

students' experience in school, however, none that we uncovered followed the lead of science studies (cf. Biagioli, 1999) in seeking to *simultaneously* study these sorts of social organizational practices of schooling *and* the epistemic practices of student work across the school day.⁶ In this regard, past ethnographic research in schools, like the cognitivist research described earlier, has not taken up the comparative questions we are asking.

Left with this lacunae in two leading traditions of educational research, we undertook a classroom-based study comparing students' understandings in two school subjects: history and science. The research approach we took is best described by the term *design experiment* (Brown, 1992; Collins, 1992).⁷ Since the meaning and practice of design experiments are currently unsettled (Barab & Squire, 2004; Kelly, 2003), we will explain how we interpreted and employed the idea in our project. In introducing our specific project, we will position it as only one research approach among many that might contribute to the development of a comparative understanding of school subjects. In fact, our methodological review begins with two more established approaches to conducting classroom research, namely, non-interventionist, ethnographic field studies and experimental studies that intervene through elicitation strategies such as structured interviewing and the administration of cognitive tasks. We compare the relative strengths and weaknesses of these approaches for developing a comparative understanding of school subjects, leading to an articulation of why we initially entered this research using a design experiment approach.

Possible Approach 1: Ethnographic Studies Following Students Across the School Day

One approach to exploring how students and teachers experience the connectedness, or lack thereof, of school subjects could be exclusively naturalistic and non-interventionist. As our questions can be framed as basic ethnographic ones, we could sensibly follow particular students *across* the school day, from language arts to science to history to mathematics (cf. Barker, Wright, & Barker, 1966). In such a study, we would seek to understand through an analysis of students' speech and actions how they display senses of connection and disconnection toward school subjects—epistemically, practically, and emotionally.

Several empirical possibilities suggest possible outcomes of this kind of fieldwork. These include:

1. Following students across subjects might allow us to see the emergence of the familiar divide between the sciences and the humanities (Bruner, 1985, 1986; Snow, 1959).⁸ We might see that students begin to identify subjects such as language arts and history as “theirs,” and see others such as mathematics and science as “not for them” (or vice versa). If this divide emerges early in school life, it would be worth knowing under what organizational conditions and on what developmental timelines it does so.

2. Another possibility we might find is that the structure of the school is an enormously powerful form of social organization that balkanizes the subjects, making them seem like entirely different and unconnected kinds of activities to students and teachers. This possibility seems plausible because the infrastructure of schools is organized to keep the subjects distinct. Time, space, materials, and teaching labor are all typically separated across subjects. This is less true in the earlier grades but increasingly true as students move through elementary, middle, secondary, and post-secondary

education. This increase in the subject-specific organization of school suggests that students' sense of balkanization would develop as they progress through the system.

3. Alternatively, we might find unexpected situations in which students make connections across subjects. Sensitivity to the social and temporal structure of the school day suggests where we could look for connections between subjects in our field research: at the actual temporal boundaries between them. For example, if the history period follows the science period, and student work continues in the interim, this might be a strategic site to locate *leakage* of thoughts and practices across these subjects.⁹

4. Finally, a comparative ethnography of school subjects might show (again) that we have seriously underestimated the capacities of school-aged children (Bransford et al., 1999; A. L. Brown & Campione, 1990; A. L. Brown & Reeve, 1987; Herrenkohl, Palincsar, DeWater, & Kawasaki, 1999; Metz, 1995). Perhaps students are making thoughtful connections across subjects all the time. For example, when talking about history and literature, students may spontaneously determine that both subjects contain stories at their heart, but that the stories in literature class are “made up” while the stories in history are “real.” All of these possibilities suggest that an ethnographic program of research following students across the school day would be illuminating.

Possible Approach 2: Elicitation to Probe Students' Understandings of Subjects

Another paradigm to consider when studying a comparative understanding of school subjects uses different types of elicitation, through clinical interviews and/or the administration of cognitive tasks. This paradigm is well established in psychologically based research on single school subjects. The misconceptions literature in physics (D. E. Brown & Clement, 1989; Clement, 1982, 1983) is a good example of how these methods

have been used to document students' ideas about the physical world. Similar studies have been conducted in mathematics (J. S. Brown & Burton, 1978), history (Barton, 1997; Seixas, 1994; VanSledright, 2002; Wineburg, 1991a), and language arts (Peskin, 1998).

As with an ethnographic approach to studying students' comparative experiences of school subjects, we believe that an elicitation approach—in the form of posed tasks and interviewing—could tell us something about students' comparative understandings. In general, these laboratory-based elicitation strategies might allow us to bring to the surface comparative understandings that would otherwise remain submerged, because students had never before had reason nor occasion to demonstrate them. Asking students directly “What are the differences between the stories you read in English class and those that you read in history class?” or “Are there differences between the problems you solve in your math class and in your chemistry class?” would provide comparative understandings that the field currently lacks.

Possible Approach 3: Classroom Design Experiments

Although we have argued for the value of two approaches (ethnography and elicitation) for developing a comparative understanding of school subjects, in our initial foray into the topic we pursued neither approach. Indeed, the approach we selected, that of a *design experiment*, blurs together elements of both elicitation and ethnography. For some commentators this blurring is a clear limitation of the approach (Shavelson, Phillips, Towne, & Feuer, 2003), while for others it is a compromise that addresses the ongoing dilemma of doing basic research in educational settings while at the same time

supporting and improving educational practices for the students and teachers participating in the experiment (A. L. Brown, 1992).

Despite ongoing controversies over the status of design experiments, we present two arguments for this approach to developing a comparative understanding of school subjects. First, we describe what we saw as the limitations of the more common ethnography and elicitation approaches for answering, in our particular research context, the kinds of comparative questions we believe have gone unasked. Second, we submit our recent project as a case study so that readers may make their own assessments of our approach to pursuing a comparative understanding of school subjects. Our purpose is not to foreclose the value of other approaches, but in fact the opposite—to engender debate about the best ways to achieve a comparative understanding. Toward this goal, we conclude this article by setting aside our own research project and offering a sketch of what we believe a broadly comparative program of research on school subjects might entail, as a collective endeavor for the field.

Regarding an ethnographic approach, we have only one substantial reservation with respect to our research focus.¹⁰ That is, we believe that the phenomenon of interest—students' comparative understandings of school subjects—would be very hard to locate empirically. The reason is that the culture of school provides neither situated motive nor opportunity for the display of these connections. In other words, making such connections publicly would likely be out of place in most school settings. Our concern is that this fact of school culture would lead to a significant underreporting of the connections students might otherwise make *under even minimal shifts in the material and communicative contexts of activity*. By analogy, consider an accomplished cook whose

day job is that of an auto mechanic. We would expect this cook to have few occasions to display her cooking knowledge during her day job, but in other contexts, such as in the kitchen, among friends and family after work hours, we would expect this knowledge to be quite visible.

We also see limitations to using an elicitation paradigm to develop a comparative understanding of school subjects. Our foremost concern is that this strategy would not answer our basic research question—about students' comparative understandings formed and used *in the context of the school day*. If a program of research takes the contexts of elicitation and data gathering at all seriously as a methodological issue, then any laboratory findings would have an uncertain relation to what students can and actually do in school. Well-designed tasks might provide an indication of students' capacities to engage in disciplinary comparison, but, because of the nature of experimental elicitation, would not tell us whether students spontaneously think about disciplinary similarities and differences if they were not prompted by the momentary demands of the interview situation (Cole & Means, 1981).

Differences between the kinds of analytic inferences that may be drawn from out-of-setting elicitation strategies and in-setting observation and recording have been recognized for decades (Becker & Geer, 1957). What is at stake is ecological validity, an issue that has haunted social science research at least since the 1940s, when Kurt Lewin and Egon Brunswik debated the relations of psychological tasks to their meaning for the lived experiences of research subjects (Brunswik, 1943; Lewin, 1943). Six decades after that debate, there is still no settlement that legitimately balances ecological validity and experimental control under a single logic of inquiry (Cole, McDermott, & Hood, 1978).

As a result, research paradigms typically sacrifice one feature for the other—with psychologists generally forsaking ecological validity, and ethnographers of everyday cognition generally forsaking experimental control. Arguably, in the debate about epistemological and educational values of design experiments, some version of tension between ecological validity and experimental control lies just beneath the surface. In light of this seemingly intractable cross-disciplinary tension, one reasonable course of action is to eschew the technical purity of both positions, and pursue a hybrid approach.

For our project, a design experiment (A. L. Brown, 1992; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Cole, 1996; Collins, 1992; Design-Based Research Collective, 2003) represented an appropriate hybrid for exploring students' comparative understandings of school subjects. However, because the definition of "design experiments" is slippery and contested, we preface the description of our project with a more general articulation of the term.

Perhaps the most widely recognized feature of design experiments is that they involve the iterative refinement of an educational innovation in a real educational setting, usually a classroom. This feature alone hardly distinguishes design experiments from traditional action research (McNiff, 1988, 1993; Quigley & Kuhne, 1997). What makes design experiments different is that they are conducted as an open research process, aimed at developing grounded understandings of learning and activity (A. L. Brown, 1992; Cole, 1996; diSessa, 1991; Newman, Griffin, & Cole, 1989).

This feature of design experiments emphasizes the sense in which they are *experiments*. Design experiments are not necessarily conducted only to address known educational problems with socio-technical innovations. Where existing theory is thin (as

in the case with students' comparative subject-matter understanding), early cycles of design experimentation are often conducted to explore more inchoate research conjectures and establish empirical boundaries on a question of interest. As in diSessa, et al. (1991), an extended classroom intervention can produce a durable phenomenon of interest—in diSessa's case, meta-representational competencies—and allow for empirical study, theory development, and subsequent educational interventions tied to the refined theoretical account (diSessa, in press).

We began our project with an initial conjecture—that elementary school is not organized for students to develop comparative understandings of school subjects, but that these understandings could be cultivated under conditions possible within ordinary classrooms. Befitting the experimental dimension of design experiments, our emerging data analyses entertain four distinct empirical possibilities related to this conjecture: (1) that comparative understandings among students were apparent at the outset, (2) that the conditions we fostered in the classroom failed to establish discipline-specific understandings, similar to outcomes in prior integrated and interdisciplinary approaches (cf. Wineburg & Grossman, 2000), (3) that the conditions we hoped to create would cultivate discipline-specific understandings in each subject but not comparative understandings, and finally, (4) that these conditions cultivated both discipline-specific and comparative understandings. Cobb, et al. (2003) describe one of the theoretical goals of design experiments as “creat[ing] the conditions for developing theories yet plac[ing] these theories in harm's way” (p. 10). By considering these different outcomes, we have placed our initial conjectures in harm's way.

An Illustrative Case: The PATHS Project

Our project, “Promoting Argumentation through History and Science” (PATHS), involved a three-year comparative study of two subjects, science and history, in a group of fifth- and sixth-grade classrooms. We selected science and history as starting points because these subjects offered ample opportunities for exploring both similarities and differences among school subjects. Returning to the scenario from the beginning of this article, let us consider “cause” as an example of a key concept in both science and history (less so in mathematics).

Studies of adult disciplinary practice suggest that cause—or more precisely, causal explanation—refers to different practices in science and history because different epistemic criteria apply. For example, single-source causal explanations are typically sought in science and valued as elegant, whereas in history, single-source explanations are typically distrusted; historical explanations posed in terms of multiple causation are generally regarded as more sophisticated, since they are viewed as better representing the ontology of historical events (Hexter, 1971; Q. Skinner, 1988). Despite differences in causal explanation, common points between science and history can be identified. For example, practitioners in both fields seek to answer some versions of “why” questions, and in both history and science practitioners use evidence to provide these answers. Such differences and similarities point to causal explanation and other overlapping themes as legitimate starting points for our comparative research.

Design Principles

As an approach, design experiments thrust researchers into two distinct but blurred roles—as designers of materials and activities for classroom use, and as empirical social scientists seeking to understand human learning. In the former role, we adopted

two principles in designing materials and activities for our comparative understanding of science and history. First, we designed our approach to enable and enhance the comparability of students' activities across subjects, and second, we sought to bring students into contact with representations of each subject displaying a reasonable fidelity to the disciplinary practices of adult professionals in each field. Attending to these principles led us to build our activities around a representational practice central to nearly all disciplinary knowledge creation: reason-giving, evidence-based *argumentation* (Toulmin, 1958; Willard, 1989). In short, we are comparing how students make arguments in each subject.

Design of Materials and Activities

For both subjects we created materials (or adapted existing ones) that allowed us to pose scientific and historical questions to students. Based on these questions, students were asked to take positions and argue for them based on evidence. The activity structures we organized in the classroom were familiar to project-based instruction; students worked in groups on questions and brought their ideas to the whole class for teacher-led discussions of their arguments. In history, we posed two questions regarding the Rosa Parks bus incident that helped spark the Civil Rights movement: where was Rosa Parks sitting and why did she stay in her seat? We then provided student groups with possible evidence that they weighed, evaluated, and selected to craft an argument for a particular position. In science, we adapted existing materials (Herrenkohl & Guerra, 1998) that asked students to conduct inquiry experiments on why objects sink or float. Based on their experiments, students were asked to assemble arguments to explain these phenomena and, as in history, present their arguments to the whole class.

Forms of Data and Analysis

Asking students to make arguments for their ideas about phenomena in history and science has led us to collect a range of data from classroom activities. However, our main corpus of data came in the form of audio-video recordings of students and teachers working together, as they made, refined, and critiqued arguments. Some of this classroom talk involved students interacting with each other in groups as they tried to collectively build arguments. Using other data collected, we were trying to evaluate students' talk as they presented their group work to their classmates, who then raised questions about the claims, evidence, and warrants that constituted these arguments. Teachers played a central role in these discourse activities, by asking questions of their own but also by maintaining conversational norms of question-asking and responding.

In our analysis of this discourse data, we are making comparisons at a number of levels of discourse organization. At the word level, we are comparing the meanings with which students use common words such as "cause," "argument," and "proof" across the subjects. At higher levels of discourse organization, we are comparing the structure of students' arguments in both subjects as they played out in talk, both in more monologic presentational forms and in multi-party interactional ones. We are also studying the "migration" of language across the subjects. For example, in a science unit that followed a history unit in one classroom, students began discussing the "sourcing" of scientific evidence, a term introduced as a heuristic in the history units (cf. Wineburg, 1991b).

Studies of discourse and interaction are increasingly common in classroom subject matter studies (cf. Boaler, 2000; Hicks, 1996; Lampert & Blunk, 1998; Lemke, 1990). We have selected this area as our focus for several reasons. At the most basic

level, we are interested in questions of comparative understanding of school subjects in the context of the school day, and talk is arguably the primary representational medium through which school subjects are transacted. More specifically, because our main interest has been in argument-making practices, we viewed talk as the mode of expression in which we could expect the most widely distributed competence across the participating students. This view is based on a basic understanding that speech is central to the development of other representational genres (Vygotsky, 1981, 1987; Wertsch, 1985). Ethnographically-based language studies show that there are many situations in which children of this age already display the capacity to engage in proto-forms of disciplined argumentation (Ochs, Taylor, Rudolph, & Smith, 1992). A related developmental basis for the focus on talk follows Vygotsky (1981) in conceptualizing argument as a practice first learned in interaction with others, prior to becoming one that people demonstrate autonomously. One implication we drew from the developmental priority of the inter-actional to the intra-actional is that, for elementary school children, interactionally-based activities provide the most supportive context for argument-making.¹¹

We therefore assembled parallel corpora of data in which students craft, refine, and share their arguments about phenomena in each subject. The contexts of talk that we recorded include small-group work, where the construction of arguments is most visible, and whole-class presentations, where more settled products of group activity are shared, critiqued, defended, and revised. It is with these data that we are seeking to answer questions about how students make arguments similarly and differently across science and history.

Seen from another perspective, our analyses of classroom interaction are focused on identifying “what counts” to students. Studying what counts is a basic premise of ethnomethodological studies of epistemic topics (Coulter, 1989; Lynch, 1991; Stevens, 2000b; Stevens & Hall, 1998). In our project, for example, we are trying to understand “what counts” for students as good (or bad) evidence in the science activities versus “what counts” in history. Do students apply similar criteria in each subject (e.g., trustworthiness) when assessing the pieces of evidence used in making their arguments? Do they hold arguments in each subject accountable to similar standards of provability?

Additionally, we collected data on classroom conversations during which we sought to bring students' comparative understandings into direct contact. We did this in two ways. One was to create interdisciplinary activities in which students could draw upon *both* science and history knowledge to address a particular question. For example, we created a short unit around the historical and scientific issue of spontaneous generation, a hypothesized biological process vigorously debated in the late seventeenth century. By engaging students in this unit, we have been able to see how students weighed knowledge-making practices from both subjects around a common question. We sought to understand when and if students took a historical perspective on the question or a scientific one. Would they intermingle perspectives?

Across our analyses, we are seeking to balance an openness to emergent questions and themes, as advocated in an interactionist approaches to social life (Blumer, 1969; Strauss & Corbin, 1998) with certain questions (what Blumer called “sensitizing constructs”) brought to the analysis from our understanding of the disciplinary practices of science and history, both among professionals and schoolchildren. Some of these are

general and would therefore be relevant to comparisons across other subjects as well. These include: How do students understand how new questions are generated in each subject? How do students understand the ways in which knowledge in the discipline is related to prediction and control of phenomena? And how do they understand the appropriate genres for constructing and representing knowledge in each subject (e.g., narrative versus propositional)? Some questions more specific to our focus on argumentation in history and science include: How do students understand what counts as a “good” argument, and what constitutes “good” evidence in each subject? How do students understand the achievement of closure in argument-making in each subject? What is the role of context in making and interpreting arguments?

The Comparative Understanding of School Subjects: A Wider Agenda

Here we set aside our specific research project and address what we see as issues in the wider program of a comparative understanding of school subjects. We raise questions that we think need to be asked, and speculate, in broad outline, about studies that might be organized to answer these questions. We describe this larger program in terms of different dimensions of comparative studies. These include comparisons across all subjects of the school day (i.e., not just history and science); across subject matter experience in and out of school; across subject matter experience over many years of schooling; and across different ethnic, national and geographic contexts. What unites these different dimensions is a steadfast focus on the phenomenology of students’ experiences of subject matter, and the contexts in which they are developed and displayed.

A complete comparative understanding of school subjects would involve all school subjects. Science and history represent one pair within a larger combinatorial universe, and many other combinations appear to us as equally fruitful for comparative study. For example, it would be illuminating to conduct a comparative study of students' understandings of literature and history around the topic of narrative. How would the "what counts" question play out in this comparative context? How do students understand similarities and differences in the construction of a good or believable narrative in history and literature? Another pair of comparative subjects to study could be mathematics and science, organized around the topic of proof. In both cases, practitioners understand themselves to prove things, but again we wonder how students would comparatively define a "proof." Perhaps a more farfetched, but in our view compelling exercise would be to look at how notions of experiment are understood across art and science. We might expect students' comparative understandings of "experiment" to be quite different in these subjects, but then again, following Dewey (1934), we might also find significant areas of overlap (cf. Eisner, 2002).

Another dimension of a research program on comparative understandings would involve the understudied topic of the relationship between subject-matter knowledge as it is displayed inside and outside of school. For example, how does the development of mathematical knowledge compare inside school and out (Lave, 1988; Rogoff & Lave, 1986; Stevens, 1999, 2000a)? How is school knowledge used outside of school? How do students read for meaning inside school and out (Mosborg, 2002)? How do students reconcile historical narratives learned in school with those absorbed by watching popular

movies (Dimitriadis, 2000; Seixas, 1994; Wineburg, 2001; Wineburg & Martin, 2004; Wineburg, Mosborg, & Porat, 2001)?

Yet another comparative dimension of the wider research program would involve understanding the evolving experience of subjects for students in successive grades. How does the meaning of what counts as knowledge in mathematics, science, history, and English change for students, from elementary school through high school, and on to college? Does a subject become more or less relevant to students' personal lives? Do students' understandings deepen, spiral, or fragment? Does subject-matter knowledge become more "conceptual," as one line of academic wisdom would have us believe, or does it become more "practical," as may be argued from other theoretical perspectives?

A particularly important type of grade transition falls between sequenced educational institutions, such as high school and college. If we accept that different educational institutions enact disciplines differently (Traweek, 1988), these transitions should be of great interest. For example, reforms to high school Advanced Placement calculus made during the last decade, spurred by National Council of Teachers of Mathematics (NCTM) standards, now highlight a version of calculus that focuses almost as much on visual-graphic reasoning as symbolic, equation-based problem-solving. At the same time, college calculus courses appear to be taught largely within the traditional equation-based mode.¹² What will transitions be like for AP students crossing the boundary from high school to college?

A final dimension of comparative research on school subjects would involve studying how academic subjects are experienced by students across cultural, ethnic, geographic and national boundaries. How does a particular history of the American Civil

War play out for students living in South Carolina versus those in New York City? Or similarly, for African-American versus Caucasian-American students (Epstein, 2000; Horwitz, 1998; Stearns, Seixas, & Wineburg, 2000; cf. Wertsch, 2002)? How does an understanding of American literature develop for students in Moscow or Toronto? A good example of this kind of work is found in the Third International Mathematics and Science study (TIMSS) (Stigler & Hiebert, 1999), which found that students in various countries received significantly different types of mathematics instruction. What effects do these differences have on the students' understandings of the subject? And what implications do these differences have for their post-instructional futures?

We have presented a range of different dimensions along which comparative research on school subjects could be conducted. Our purpose here is not to limit the range of possibilities, but to suggest that when we look at school subjects from a comparative perspective, new questions emerge. Questions of interest extend well beyond those that we have explored in our comparative research on science and history. And, as we will argue in our concluding section, this broader program of research, in addition to giving us a new vantage point on student learning, may offer promising resources for reconstructing subject-matter-based educational practices.

Conclusion

We have argued for a comparative approach to studying subject-matter learning in school. This argument has been based primarily on a perceived imbalance between how little we know about the whole (i.e., students' experience of the whole school day) versus how much we know about its parts (i.e., subject-specific studies). Our stance is based on a strong sense that previous research on subject-specific learning, while representing a

critical phase in the overall history of learning research, has not been specific enough. Where this line of research has lacked specificity is in its focus on what we have called the phenomenology of student experience, embedded in the temporal, material, emotional, and social-organizational conditions of the school day. These conditions frame how students learn academic subjects, but are underrepresented in content-focused studies of subject-matter learning. In the main, we have wondered and worried about whether the epistemological specificity of subjects, so real to researchers, is anywhere near as real to students. We are therefore arguing for a full-blown comparative focus, not only across students' experience of the sequenced subjects of the school day, but across their subject-related experiences in and out school.

What our project did for two subjects in several elementary school classrooms could be broadened to permutations across all the subjects. This would involve a more dramatic reconstruction of the school experience than the one we have orchestrated in our design experiment. Such a reconstruction would by no means need to displace the subject-specific organization of education, but it would entail creating more deliberate connective tissue across the subjects. Under such a systematic reconstruction, subject matter educators would help students learn what is unique about a discipline as a way of knowing by learning how that way of knowing compares to others.

This type of systematic reconstruction could, in turn, raise new research questions about educational practice. Would such a reconstruction make school learning more meaningful to students by allowing them to see scholastic practice as a multi-faceted but connected approach to experience (i.e., overlapping sets composed of sometimes similar and sometimes different ways of making and using knowledge)? Would it enrich

students' understandings of specific subjects to embed these subjects in a comparative matrix? Would this reconstruction make teaching easier and more rewarding, especially for those teachers who teach multiple subjects in a given day? Alternatively, might it make teaching them more difficult, because it would require adding to an already overcrowded school curriculum?

Andrea diSessa (1988, 2002) has argued that one of the defining differences between the disciplinary knowledge of novices and that of experts is that novices have “knowledge in pieces,” whereas experts have knowledge that is densely connected and richly differentiated. However accurate this may be as a description of individual minds, we see it as a compelling point about *our* collective understanding of school subjects. At present, our knowledge of school subjects is in pieces. We may do a better job at making school a meaningful place for students to learn and for teachers to teach if we can put these pieces together.

References

- Adler, M., & Flihan, S. (1997). *The interdisciplinary continuum: Reconciling theory, research and practice*. Albany, NY: National Research Center on English Learning and Achievement.
- Aiken, W. M. (1942). *The story of the eight-year study*. New York: Harper & Brothers.
- Anderson, J. R., Reder, L. M., & Simon, H. A. (1996). Situated learning and education. *Educational Researcher*, 25, 5-11.
- Anderson, J. R., Reder, L. M., & Simon, H. A. (1997). Rejoinder: Situative versus cognitive perspectives: Form versus substance. *Educational Researcher*, 26, 18-21.
- Ball, D. L. (1988). *Knowledge and reasoning in mathematical pedagogy: Examining what prospective teachers bring to teacher education*. Unpublished doctoral dissertation, Michigan State University, East Lansing.
- Ball, D. L. (1993). With an eye on the mathematical horizon: Dilemmas of teaching elementary school mathematics. *Elementary School Journal*, 93 (4), 373-397.
- Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *Journal of the Learning Sciences*, 13, 1-14.
- Barton, K. C. (1997). "Bossed around by the queen": Elementary students' understanding of individuals and institutions in history. *Journal of Curriculum and Supervision*, 12, 290-314.
- Barker, R. G., Wright, H. F., & Barker, L. (1966). *One boy's day: A specimen record of behavior*. Hamden, CT: Archon Books.

- Bauman, R. (1982). Ethnography of children's folklore. In P. Gilmore & A. Glatthorn (Eds.), *Children in and out of school* (pp. 172-186). Washington, DC: Center for Applied Linguistics.
- Beane, J. A. (1995). Curriculum integration and the disciplines of knowledge. *Phi Delta Kappan*, 84, 616-622.
- Becher, T. (1989). *Academic tribes and territories: Intellectual enquiry and the culture of disciplines*. Milton Keynes, England: Open University Press.
- Becker, H. (1972). School is a lousy place to learn anything. *American Behavioral Scientist* 16, 85-105.
- Becker, H., & Geer, B. (1957). Participant observation and interviewing: A comparison. *Human Organization*, 16, 28-32.
- Bell, P. (2002). Using argument map representations to make thinking visible for individuals and groups. In T. Koschmann, R. Hall, & N. Miyake (Eds.), *CSCL2: Carrying forward the conversation* (pp. 449-485). Mahwah, NJ: Lawrence Erlbaum.
- Biagioli, M. (Ed.). (1999). *The science studies reader*. New York: Routledge.
- Blumer, H. (1969). *Symbolic interactionism: Perspective and method*. Berkeley, CA: University of California Press.
- Boaler, J. (Ed.). (2000). *Multiple perspectives on mathematics teaching and learning*. Toronto: Ablex.
- Boix-Mansilla, V., & Gardner, H. (1994). Teaching for understanding in the disciplines - and beyond. *Teachers College Record*, 96, 198-218.

- Booth, M. (1994). Cognition in history: A British perspective. *Educational Psychologist*, 29, 61-70.
- Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (1999). *How people learn: Brain, mind, experience, and school*. Washington DC: National Academy Press.
- Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of Learning Sciences*, 2, 141-178.
- Brown, A. L., & Campione, J. C. (1990). Communities of learning and thinking, or a context by any other name. In D. Kuhn (Ed.), *Developmental perspectives on teaching and learning thinking skills* (pp. 108-126). New York: Karger.
- Brown, A. L., & Reeve, R. A. (1987). Bandwidths of competence: The role of supportive contexts in learning and development. In L. S. Liben (Ed.), *Development and learning: Conflict or congruence?* (pp. 173-235). Hillsdale, NJ: Lawrence Erlbaum.
- Brown, D. E., & Clement, J. (1989). Overcoming misconceptions via analogical reasoning: Abstract transfer versus explanatory model construction. *Instructional Science*, 18, 237-261.
- Brown, J. S., & Burton, R. R. (1978). Diagnostic models for procedural bugs in basic mathematical skills. *Cognitive Science*, 2, 155-192.
- Brown, J. S., Duguid, P., & Collins, A. (1989). Situated cognition and the culture of learning. *Educational Researcher*, 18, 32-42.
- Bruner, J. S. (1960). *The process of education*. Cambridge, MA: Harvard University Press.

- Bruner, J. S. (1966). *Toward a theory of instruction*. Cambridge, MA: Harvard University Press.
- Bruner, J. S. (1983). *In search of mind: Essays in autobiography*. New York: HarperCollins.
- Bruner, J. S. (1985). Narrative and paradigmatic ways of knowing. In E. Eisner (Ed.), *Learning and teaching the ways of knowing* (pp. 97-115). Chicago: University of Chicago Press.
- Bruner, J. S. (1986). *Actual minds, possible worlds*. Cambridge, MA: Harvard University Press.
- Bruner, J. S. (1990). *Acts of meaning*. Cambridge, MA: Harvard University Press.
- Brunswik, E. (1943). Organismic achievement and environmental probability. *Psychological Review*, 50, 255-272.
- Capenhart, B. E. (1958). Illustrative courses and programs in selected secondary schools. In N. B. Henry (Ed.), *The integration of educational experiences: The 57th Yearbook of the National Society for the Study of Education* (pp. 194-217). Chicago: University of Chicago Press.
- Carpenter, T. P., Fennema, E., Franke, M. L., Empson, S. B., & Levi, L.W. (1999). *Children's mathematics: Cognitively guided instruction*. Portsmouth, NH: Heinemann.
- Case, R. (1994). Our crude handling of educational reform: The case of curriculum integration. *Canadian Journal of Education*, 19, 80-93.
- Cawelti, G. (1994). *High school restructuring: A national study*. Arlington, VA: Educational Research Service.

- Cazden, C. (1986). Classroom discourse. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (pp. 119-160). New York: Macmillan.
- Cazden, C. (1988). *Classroom discourse: The language of teaching and learning*. Portsmouth, NH: Heinemann.
- Chase, W. G., & Simon, H. A. (1973). Perception in chess. *Cognitive Psychology, 1*, 55-81.
- Chi, M. T. H., Feltovich, P. J., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science, 5*, 121-152.
- Chi, M. T. H., & Koeske, R. D. (1983). Network representations of a child's dinosaur knowledge. *Developmental Psychology, 19*, 29-39.
- Clement, J. (1982). Students' preconceptions in introductory mechanics. *American Journal of Physics, 50*, 66-71.
- Clement, J. (1983). A conceptual model discussed by Galileo and used intuitively by physics students. In D. Gentner & A. L. Stevens (Eds.), *Mental models* (pp. 325-340). Hillsdale, NJ: Erlbaum.
- Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher, 32*, 9-13.
- Cobb, P., Wood, T., & Yackel, E. (1991). Learning through problem solving: A constructivist approach to second grade mathematics. In E. von Glasersfeld (Ed.), *Constructivism in mathematics education* (pp. 157-176). Dordrecht, Holland: Reidel.
- Cole, M. (1996). *Cultural psychology: A once and future discipline*. Cambridge, MA: Harvard University Press.

- Cole, M., McDermott, R. P., & Hood, L. (1978). Concepts of ecological validity: Their differing implications for comparative cognitive research. *Quarterly Newsletter of the Laboratory of Comparative Cognition*, 2, 34-37.
- Cole, M., & Means, B. (1981). *Comparative studies of how people think: An introduction*. Cambridge, MA: Harvard University Press.
- Collins, A. (1992). Toward a design science of education. In E. Scanlon & T. O'Shea (Eds.), *New directions in educational technology* (pp. 15-22). New York: Springer-Verlag.
- Coulter, J. (1989). *Mind in action*. Atlantic Highlands, NJ: Humanities Press International.
- Covington, M. V., Crutchfield, R. S., Davies, L., & Olton, R. M. (1974). *The productive thinking program: A course in learning to think*. Columbus, OH: Charles E. Merrill.
- de Bono, E. (1985). The CoRT thinking program. In J. W. Segal, S. F. Chipman, & R. Glaser (Eds.), *Thinking and learning skills: Relating instruction to basic research* (Vol. 1) (pp. 363-387). Hillsdale, NJ: Erlbaum.
- Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher*, 32, 5-8.
- Devine, J. (1996). *Maximum security: The culture of violence in inner-city schools*. Chicago: University of Chicago Press.
- Dewey, J. (1934). *Art as experience*. New York: Perigee.

- Dimitriadis, G. (2000). "Making history go" at a local community center: Popular media and the construction of historical knowledge among African American youth. *Theory and Research in Social Education*, 28, 40-64.
- diSessa, A. (1982). Unlearning Aristotelian physics: A study of knowledge-based learning. *Cognitive Science*, 6, 37-75.
- diSessa, A. (1988). Knowledge in pieces. In G. Forman & P. B. Purall (Eds.), *Constructivism in the computer age* (pp. 49-70). Hillsdale, NJ.: Lawrence Erlbaum.
- diSessa, A. (1991). Local sciences: Viewing the design of human computer systems as cognitive science. In J. M. Carroll (Ed.), *Designing interaction: Psychology at the human-computer interface* (pp. 162-202). New York: Cambridge University Press.
- diSessa, A. (2002). Why "conceptual ecology" is a good idea. In M. Limón & L. Mason (Eds.), *Reconsidering conceptual change: Issues in theory and practice* (pp. 29-60). Dordrecht: Kluwer.
- diSessa, A. A. (in press). Meta-representation: Native competence and targets for instruction. In S. Strauss (Ed.), *The development of notational representations*. Oxford, UK: Oxford University Press.
- diSessa, A., Hammer, D., Sherin, B., & Kolpakowski, T. (1991). Inventing graphing: Meta-representational expertise in children. *Journal of Mathematical Behavior*, 10(2), 117-160.
- Dow, P. (1991). *Schoolhouse politics: Lessons from the Sputnik era*. Cambridge, MA: Harvard University Press.

- Eckert, P. (1989). *Jocks and burnouts: Social categories and identity in the high school*. New York: Teachers College Press.
- Eder, D., Evans, C. C., & Parker, S. (1995). *School talk: Gender and adolescent culture*. New Brunswick, NJ: Rutgers University Press.
- Eisner, E.W. (2002). *Arts and the creation of mind*. New Haven: Yale University Press.
- Epstein, T. (2000). Adolescents' perspectives on racial diversity in U.S. history: Case studies from an urban classroom. *American Educational Research Journal*, 37, 184-214.
- Gagné, R. M. (1965). *The conditions of learning*. New York: Holt, Rinehart, & Winston.
- Gagné, R. M. (1974). *Essentials of learning for instruction*. Hinsdale, IL: Dryden.
- Gagné, R. M. (1976). The learning basis of teaching method. In N. L. Gage (Ed.), *The psychology of teaching methods: Seventy-fifth yearbook of the National Society for the Study of Education* (pp. 22-43). Chicago: University of Chicago Press.
- Glaser, R. (1982). Instructional technology: Past, present, future. *American Psychologist*, 37, 292-305.
- Glaser, R. (1984). Education and thinking: The role of knowledge. *American Psychologist*, 39, 93-104.
- Grant, C. A., & Sleeter, C. E. (1996). *After the school bell rings*. London: Falmer Press.
- Greeno, J. (1997). On claims that answer the wrong question. *Educational Researcher*, 26, 5-17.
- Greeno, J. (1998). The situativity of knowing, learning, and research. *American Psychologist*, 53, 5-26.

- Gregory, E., Long, S., & Volk, D. (2004). *Many pathways to literacy: Young children learning with siblings, grandparents, peers and communities*. London: RoutledgeFalmer.
- Grossman, P. L. (1990). *The making of a teacher: Teacher knowledge and teacher education*. New York: Teachers College Press.
- Gump, P. S. (1967). *The classroom behavior setting: Its nature and relationship to student behavior*. Washington, DC: U.S. Office of Education, Bureau of Research (ERIC Document Reproduction Service No. ED 015-515).
- Hammerness, K., & Moffett, K. (2000). The subjects of debate: Teachers' clashing and overlapping beliefs about subject matter during a whole-school reform. In S. Wineburg & P. Grossman (Eds.), *Interdisciplinary curriculum: Challenges to implementation* (pp. 134-152). New York: Teachers College Press.
- Heath, S. B. (1982). Questioning at home and at school: A comparative study. In G. Spindler (Ed.), *Doing the ethnography of schooling: Educational anthropology in action* (pp. 103-113). New York: Holt, Rinehart, & Winston.
- Heath, S. B. (1983). *Ways with words: Language, life, and work in communities and classrooms*. New York: McGraw-Hill.
- Henry, N. B. (Ed.). (1958). *The integration of educational experiences*. Chicago: University of Chicago Press.
- Herrenkohl, L. R., & Guerra, M. R. (1998). Participant structures, scientific discourse, and student engagement in fourth grade. *Cognition and Instruction, 16*, 433-475.

- Herrenkohl, L. R., Palincsar, A. S., DeWater, L. S., & Kawasaki, K. (1999). Developing scientific communities in classrooms: A sociocognitive approach. *Journal of the Learning Sciences*, 8, 451-493.
- Hexter, J. H. (1971). *The history primer*. New York: Basic Books.
- Hicks, D. (Ed.). (1996). *Discourse, learning, and schooling*. Cambridge, UK: Cambridge University Press.
- Hirst, P. (1973). Liberal education and the nature of knowledge. In R. S. Peters (Ed.), *Philosophy of education* (pp. 87-101). Oxford, UK: Oxford University Press.
- Horwitz, T. (1998). *Confederates in the attic: Dispatches from the unfinished Civil War*. New York: Vintage.
- Hoskin, K. W. (1993). Education and the genesis of disciplinarity: The unexpected reversal. In E. Messer-Davidow, D. R. Shumway, & D. J. Sylvan (Eds.), *Knowledges: Historical and critical studies in disciplinarity* (pp. 271-304). Charlottesville, VA: University of Virginia Press.
- Husbands, J., & Beese, S. (2001, July). *Review of selected high school reform strategies*. Paper prepared for the Aspen Program on Education, Aspen Meadows, Aspen, CO.
- Jackson, P. W. (1968). *Life in classrooms*. New York: Holt, Rinehart, & Winston.
- Kelly, A. (2003). The role of design in educational research. *Educational Researcher*, 32, 3-4.
- Kiewra, K. A., & Dubois, N. F. (1998). *Learning to learn: Making the transition from student to life-long learner*. Englewood Cliffs, NJ: Prentice Hall.

- Klein, J. T. (1990). *Interdisciplinarity: History, theory, practice*. Detroit, MI: Wayne State University Press.
- Kuhn, T. (1962). *The structure of scientific revolutions*. Chicago: University of Chicago Press.
- Lakatos, I. (1978). *Mathematics, science, and epistemology*. Cambridge, UK: Cambridge University Press.
- Lampert, M. (1990). When the problem is not the question and the solution is not the answer: Mathematical knowing and teaching. *American Educational Research Journal*, 27, 29-63.
- Lampert, M., & Blunk, M. L. (Eds.). (1998). *Talking mathematics in school: Studies of teaching and learning*. Cambridge, UK: Cambridge University Press.
- Lave, J. (1988). *Cognition in practice*. New York: Cambridge University Press.
- Leinhardt, G. (1993). Weaving instructional explanations in history. *British Journal of Educational Psychology*, 63, 46-74.
- Leinhardt, G., Zaslavsky, O., & Stein, M. K. (1990). Functions, graphs, and graphing: Tasks, learning, and teaching. *Review of Educational Research*, 60, 1-64.
- Lemke, J. L. (1990). *Talking science: Language, learning, and values*. Norwood, NJ: Ablex.
- Lehrer, R., Jacobson, C., Kemeny, V., & Strom, D. (1999). Building on children's intuitions to develop mathematical understanding of space. In E. Fennema & T. A. Romberg (Eds.), *Mathematics classrooms that promote understanding* (pp. 63-87). Mahwah, NJ: Erlbaum.
- Lewin, K. (1943). Defining the field at a given time. *Psychological Review*, 50, 292-310.

- Lipman, M. (1977). *Philosophy in the classroom*. Upper Montclair, NJ: Institute for the Advancement of Philosophy for Children.
- Lynch, M. (1991). Method: Ordinary and scientific measurement as ethnomethodological phenomena. In G. Button (Ed.), *Ethnomethodology and the human sciences: A foundational reconstruction* (pp. 77-108). Cambridge, UK: Cambridge University Press.
- Macbeth, D. (1992). Classroom “floors”: Material organizations as a course of affairs. *Qualitative Sociology*, 15, 123–150.
- Macbeth, D. (2002). A commentary on instructional design. *Journal of the Learning Sciences*, 11, 373-386.
- McDermott, R. P. (1976). Making sense and feeling good: The ethnography of communication and identity work. *Communication*, 2, 121-142.
- McNiff, J. (1988). *Action research: Principles and practice*. London: Routledge.
- McNiff, J. (1993). *Teaching as learning: An action research approach*. London: Routledge.
- Mehan, H. (1985). The structure of classroom discourse. In T A. Van Dijk (Ed.), *Handbook of discourse analysis*, Vol. 3 (pp.120-132). London: Academic Press.
- Messer-Davidow, E., Shumway, D. R., & Sylvan, D. J. (Eds.) (1993). *Knowledge: Historical and critical studies in disciplinarity*. Charlottesville, VA: University of Virginia Press.
- Metz, K. (1995). Reassessment of developmental constraints on children's science instruction. *Review of Educational Research*, 65, 93-127.

- Mink, L. O. (1966). The autonomy of historical understanding. *History and Theory*, 5, 24-47.
- Moje, E. B. (2004). Powerful spaces: Tracing the out-of-school literacy spaces of Latino/a youth. In K. Leander & M. Sheehy (Eds.), *Spatializing literacy research and practice* (pp. 15-38). New York: Peter Lang.
- Moje, E. B., McIntosh Ciechanowski, K., Kramer, K., Ellis, L., Carrillo, R., & Collazo, T. (2004). Working toward third space in content area literacy: An examination of everyday funds of knowledge and discourse. *Reading Research Quarterly*, 39, 38-71.
- Mosborg, S. (2002). Speaking of history: How adolescents use their knowledge of history in reading the daily news. *Cognition and Instruction*, 20, 323-358.
- Muncey, D. E., & McQuillan, P. J. (1996). *Reform and resistance in schools and classrooms: An ethnographic view of the Coalition of Essential Schools*. New Haven: Yale University Press.
- Newell, A., & Simon, H. A. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice Hall.
- Newman, D., Griffin, P., & Cole, M. (1989). *The construction zone: Working for cognitive change in school*. New York: Cambridge University Press.
- Nolen, S. B. (1995). The effects of a visible author in statistical texts. *Journal of Educational Psychology*, 87, 47-65.
- Ochs, E., Taylor, C., Rudolph, D., & Smith, R. (1992). Story-telling as a theory-building activity. *Discourse Processes*, 15, 37-72.

- Palincsar, A. (1989). Less charted waters: Responses to Brown, Collins and Duguid's "Situated cognition and the culture of learning." *Educational Researcher*, 18, 5-7.
- Paxton, R. J. (1999). A deafening silence: History textbooks and the students who read them. *Review of Educational Research*, 69, 315-339.
- Peskin, J. (1998). Constructing meaning when reading poetry: An expert-novice study. *Cognition and Instruction*, 16, 235-263.
- Philips, S. U. (1983). *The invisible culture: Communication in classroom and community on the Warm Springs Indian Reservation*. Prospect Heights, IL: Waveland Press.
- Polya, G. (1981). *Mathematical discovery: On understanding, learning, and teaching problem solving*. New York: Wiley.
- Pope, D. C. (2003). *"Doing school": How we are creating a generation of stressed out, materialistic, and miseducated students*. New Haven, CT: Yale University Press.
- Quigley, B. A., & Kuhne, G. W. (1997). *Creating practical knowledge through action research*. San Francisco: Jossey Bass.
- Reed-Danahay, R. (1996) *Education and identity in rural France: The politics of schooling*. New York: Cambridge University Press.
- Rényi, J. (2000). Hunting the quark: Interdisciplinary curriculum in public schools. In S. Wineburg & P. Grossman (Eds.), *Interdisciplinary curriculum: Challenges to implementation* (pp. 40-53). New York: Teachers College Press.
- Rist, R. (1979). *Desegregated schools: An appraisal of an American experiment*. New York: Holt, Rinehart, & Winston.

- Rosenzweig, L. W., & Weinland, T. P. (1986). New directions of the history curriculum: A challenge for the 1980s. *History Teacher*, 19, 263-277.
- Roth, K. J. (2000). Photosynthesis of Columbus: Exploring interdisciplinary curriculum from the students' perspectives. In S. Wineburg & P. Grossman (Eds.), *Interdisciplinary curriculum: Challenges to implementation* (pp. 153-179). New York: Teachers College Press.
- Schoenfeld, A. (1985). *Mathematical problem solving*. New York: Academic Press.
- Schoenfeld, A. (1988). When good teaching leads to bad results: The disasters of "well-taught" mathematics courses. *Educational Psychologist*, 2, 145-166.
- Schwab, J. J. (1978). Education and the structure of the disciplines. In I. Westbury & N. J. Wilkof (Eds.), *Science, curriculum, and liberal education* (pp. 229-272). Chicago: University of Chicago Press.
- Seixas, P. (1994). Confronting the moral frames of popular film: Young people respond to historical revisionism. *American Journal of Education* 102, 261-285.
- Seixas, P. (1994). Students' understanding of historical significance. *Theory and Research in Social Education*, 23, 281-304.
- Shaughnessy, M. (1977). *Errors and expectations*. New York: Oxford University Press.
- Shavelson, R. J., Phillips, D. C., Towne, L., & Feuer, M. J. (2003). On the science of education design studies. *Educational Researcher*, 32, 25-28.
- Shemilt, D. J. (1980). *History 13-16: Evaluation study*. Edinburgh: Heinemann.
- Shulman, L. S. (1986). Paradigms and research programs in the study of teaching: A contemporary perspective. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed.) (pp. 3-36). New York: Macmillan.

- Shulman, L. S. (1987). Knowledge and teaching: Foundations for the new reform. *Harvard Educational Review*, 57 (1), 1-22.
- Shulman, L. S., & Quinlan, K. M. (1996). The comparative psychology of school subjects. In R. C. Calfee & D. C. Berliner (Eds.), *Handbook of educational psychology* (pp. 399-422). New York: Macmillan.
- Sizer, T. (1992). *Horace's compromise*. Boston: Houghton Mifflin.
- Skinner, B. F. (1954). The science of learning and the art of teaching. *Harvard Educational Review*, 24, 86-97.
- Skinner, Q. (1988). *Meaning and context*. Princeton, NJ: Princeton University Press.
- Snow, C. P. (1959). *Two cultures and the scientific revolution*. Cambridge, UK: Cambridge University Press.
- Stearns, P. N., Seixas, P., & Wineburg, S. (Eds.) (2000). *Knowing, teaching and learning history: National and international perspectives*. New York: NYU Press.
- Stevens, R. (1999). *Disciplined perception: Comparing the development of embodied mathematical practices in school and at work*. Unpublished dissertation, University of California, Berkeley.
- Stevens, R. (2000a). Divisions of labor in school and in the workplace: Comparing computer and paper-supported activities across settings. *Journal of the Learning Sciences*, 9, 373-401.
- Stevens, R. (2000b). Who counts what as math: Emergent and assigned problems in a project-based classroom. In J. Boaler (Ed.), *Multiple perspectives on mathematics teaching and learning* (pp. 105-144). Toronto: Ablex.

- Stevens, R., & Hall, R. P. (1998). Disciplined perception: Learning to see in technoscience. In M. Lampert & M. L. Blunk (Eds.), *Talking mathematics in school: Studies of teaching and learning* (pp.107-149). Cambridge, UK: Cambridge University Press.
- Stigler, J. W., & Hiebert, J. (1999). *The teaching gap: Best ideas from the world's teachers for improving education in the classroom*. New York: Free Press.
- Stodolsky, S. S. (1988). *The subject matters: Classroom activity in math and social studies*. Chicago: University of Chicago Press.
- Strauss, A., & Corbin, J. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory*. London: Sage Publications.
- Taber, J. I., Glaser, R., & Schaefer, H. H. (1965). *Learning and programmed instruction*. New York: Addison-Wesley.
- Tchudi, S. (1994). Interdisciplinary English and re-forming the schools. *English Journal*, 7, 54-61.
- Tchudi, S., & Lafer, S. (1996). *The interdisciplinary teacher's handbook: Integrating across the curriculum*. Portsmouth, NH: Boynton/Cook.
- Thorne, B. (1993). *Gender play: Girls and boys in school*. New Brunswick, NJ: Rutgers University Press.
- Toulmin, S. (1958). *The uses of argument*. Cambridge, UK: Cambridge University Press.
- Traweek, S. (1988). "Pilgrim's progress": Male tales told during a life in physics. In *Beamtimes and lifetimes: The world of high energy physicists* (pp. 74-105). New York: Cambridge University Press.

- Tyack, D., & Tobin, W. (1994). The “grammar” of schooling: Why has it been so hard to change? *American Educational Research Journal*, 31, 453-479.
- VanSledright, B. (2002). *In search of America's past: Learning to read history in elementary school*. New York: Teachers College Press.
- Voss, J. F., Vesonder, G. T., & Spilich, G. J. (1980). Text generation and recall by high knowledge and low knowledge. *Journal of Verbal Learning and Behavior*, 19, 651-667.
- Vygotsky, L. S. (1964). *Thought and language*. Cambridge, MA: MIT Press.
- Vygotsky, L. S. (1981). The genesis of higher mental functions. In J. V. Wertsch (Ed.), *The concept of activity in Soviet psychology* (pp. 144-188). Armonk, New York: Sharpe.
- Vygotsky, L. S. (1987). *The collected words of L.S. Vygotsky*. New York: Plenum.
- Wertsch, J. V. (1985). *Vygotsky and the social formation of mind*. Cambridge, MA: Harvard University Press.
- Wertsch, J. V. (2002). *Voices of collective remembering*. New York: Cambridge University Press.
- Whimbey, A., & Lockhead, J. (1980). *Problem solving and comprehension: A short course in analytical reasoning* (2nd ed.). Philadelphia: Franklin Institute Press.
- Willard, C. (1989). *A theory of argumentation*. Tuscaloosa, AL: University of Alabama Press.
- Willis, P. (1977). *Learning to labour: How working class kids get working class jobs*. New York: Columbia University Press.

- Wilson, S. M. (2001). Research on history teaching. In V. Richardson (Ed.), *Handbook of research on teaching* (pp. 527-524). (4th ed.). Washington, DC: American Educational Research Association.
- Windschitl, M. (2002). Framing constructivism in practice as negotiation of dilemmas: An analysis of the conceptual, pedagogical, cultural, and political challenges facing teachers. *Review of Educational Research*, 72, 131-175.
- Wineburg, S. (1989). Remembrance of theories past. *Educational Researcher*, 18, 7-10.
- Wineburg, S. (1991a). Historical problem solving: A study of the cognitive processes used in the evaluation of documentary and pictorial evidence. *Journal of Educational Psychology*, 83, 73-87.
- Wineburg, S. (1991b). On the reading of historical texts: Notes on the breach between school and the academy. *American Educational Research Journal*, 28, 495-519.
- Wineburg, S. (1998). Reading Abraham Lincoln: An expert/expert study in historical cognition. *Cognitive Science*, 22, 319-346.
- Wineburg, S. (2001). *Historical thinking and other unnatural acts: Charting the future of teaching the past*. Philadelphia: Temple University Press.
- Wineburg, S., & Grossman, P. (Eds.). (2000). *Interdisciplinary curriculum: Challenges to implementation*. New York: Teachers College Press.
- Wineburg, S., & Martin, D. (2004). Reading and rewriting history, *Educational Leadership*, 62, 42-45.
- Wineburg, S. S., & Wilson, S. M. (1988). Models of wisdom in the teaching of history. *Phi Delta Kappan*, 70, 50-58.

Wineburg, S., Mosborg, S., & Porat, D. (2001). What can *Forrest Gump* tell us about students' historical understanding? *Social Education*, 65, 55-58.

Yon, D. (2003). Highlights and overview of the history of educational ethnography. *Annual Review of Anthropology*, 32, 411-429.

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Notes

¹ For a notable exception, see the work of Elizabeth B. Moje and her colleagues (e.g., Moje, 2004; Moje, McIntosh-Ciechanowski, Kramer, Ellis, Carrillo, & Collazo, 2004).

² The terms “domain-specific,” “discipline-specific,” “subject-specific,” and “content-specific” are used in a variety of ways in the educational and psychological literatures, often with a great deal of overlap among them. In the cognitive literature, a domain can be a topic such as baseball (Voss, Vesonder, & Spilich, 1980), which is quite different from an academic discipline that constantly grows in knowledge. On the other hand, a domain can refer to a body of knowledge such as dinosaurs (Chi & Koeske, 1983) with knowledge entailments in paleontology that overlap neatly with disciplinary understandings. In this article we generally use "domain-specific" when contrasting this approach with "domain-general." When we turn to the question of academic disciplines and their school-based referents, we use "discipline-specific" whenever possible. Often, however, we use the terms "domain-specific" and "discipline-specific" interchangeably.

³ By necessity we are simplifying our storyline. Behaviorist approaches to learning remain particularly strong in areas of special education and physical education, as evinced by a casual perusal of the *Journal of Learning Disabilities* or *Journal of Applied Behavioral Analysis*. However, in this age of education reform, we are hard pressed to find programs of school learning of academic content that have not been reshaped by the shift to cognitivism.

⁴ To be sure, there remain research areas that take up school learning in the spirit of cognitivism, but which have not embraced domain-specificity. Work on motivation (cf.

Graham & Weiner, 1996) and study skills/learning strategies (Kiewra & Dubois, 1998) have “gone cognitive,” but have not elected domain-specific paths. For an approach to motivation that takes the domain of study seriously, see Nolen (1995).

⁵ The scope of reference to “understandings” is intentionally synoptic, meant to include how understandings are documented, whether through tests, experimental elicitation, or naturally occurring performance.

⁶ For a partial exception see Reed-Danahay (1996) who includes an ethnographic description of the whole school day in a rural French primary school. This description draws contrasts between the pedagogical aims of subjects that the school treats as particularly important, such as mathematics and French, and others. In this account, however, students’ epistemic practices are not brought into focus.

⁷ We use the term “design experiment” because of its currency, but wish to make clear that closely related work from a cultural-historical activity theoretic approach involving “creating model activity systems” (Cole, 1996; Newman, Griffin, & Cole, 1989) has been equally influential on our design and research practices.

⁸ Indeed, some analysts have tied the very fact of disciplinarity to the practices of schooling (Hoskin, 1993).

⁹ Rogers Hall suggested this possibility in a commentary on an earlier version of this article.

¹⁰ For purposes of this argument, we are referring to a “pure” ethnographic approach in which participants are observed and recorded but not interviewed (i.e., no elicitation). In practice, ethnographic studies often combine participant observation and informal interviewing.

¹¹ Though talk has been the primary medium through which we have sought to capture our data, we have also collected other kinds of student representations of their arguments. These include visual diagrammatic representations of arguments adapted from computer-based representations of arguments (Bell, 2002).

¹² This gap was proposed by Lari Garrison, based on her experience of teaching AP Calculus (personal communication, May 29, 2003).