Activity Structures for Project-Based Teaching & Learning: Design and Adaptation of Cultural Tools

by

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Abstract

In this paper I discuss research on activity structure design in a project-based science classroom and efforts to adapt designs from this setting to an after-school program involving historical inquiry. I point out that common activity structures such as classroom lessons and I-R-E sequences are important cultural tools that help students and teachers accomplish everyday activity, but that they are not well adapted to open-ended projects. I demonstrate how alternative activity structures scaffold children's performance of complex, open-ended projects. For the activity setting of a project-based earth science class, I show how activity structures at two different time scales support students in the accomplishment of science research. On a more long-term scale, a milestone activity structure works by laying out a small set of interim material artifacts, which students turn in over a period of weeks, each of which feeds into portions of the artifact that is the final product or milestone, a science research report. On a shorter time scale, the repetition of Bid-Negotiation-Implementation-Evaluation (B-N-I-E) and Question-Clarification (Q-C) many times helps the teacher to guide students in their work, while requiring that students remain active. For the activity setting of an after-school history-Web club, I describe how adapting the milestone activity structure across disciplines presents a number of hurdles because it depends on a discipline-specific task analysis, but the B-N-I-E discourse sequence seems generally adaptable to a wide range of inquiry-oriented work.

Introduction: Activity structures as cultural tools

The rhetoric of reform often casts teachers as individual actors who have the power to change their classrooms through sheer will. This attitude implies that teachers who do not "adopt" new teaching methods and techniques could do so if they would simply choose to change a stubborn mind-set. As researchers have long been pointing out (e.g., Doyle, 1979; Sarason, 1971), however, classrooms and schools are complex cultural systems, and teachers do not create change alone. Teachers must coordinate action with many students, and all must draw on an understanding of the cultural practices in which they are taking part in order to act.

One reason that teaching practices have been remarkably resistant to change is that they are both familiar and well-adapted to many of the goals and constraints of educators. Larry Cuban (1984) argues that school and classroom structures have hindered the spread of child-centered instruction such as that encouraged by the progressive movement and recent reforms. Specifically, schools and teachers use the various "batch processing" structures that today constitute the standard "grammar of schooling" (Tyack & Tobin, 1994) to cope with the demand of teaching and keeping in order groups of up to thirty children at once. Activities in the classroom are "structured" in the sense that they can be broken down into "functional elements [that] have specific relationships to one another, including restrictions on the order in which they can meaningfully occur" (Lemke, 1990, p. 199). Examples include school structures, such as Carnegie units of academic credits, and classroom level activity structures (Lemke, 1991)[1], such as whole group question-and-answer sessions with students arranged at desks in rows.

The dominant activity structure of teaching typified by question and answer sessions deserves a closer examination. In his observational studies of standard classroom "lessons," Hugh Mehan (1978, 1979) described how lessons are organized as sequences of events at various levels. At the most basic level, Mehan identified the dominant structure of discourse to be what he termed "Initiation-Reply-Evaluation" (I-R-E). In such a sequence, the teacher *initiates* an episode by asking a question about an established fact or idea he or she wants to convey; students *reply* with bids for correct responses; the teacher *evaluates* the responses, and may initiate another round. Jay Lemke (1990) conducted research following this same tradition in science classrooms, and

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[1] I use the term "participant structure" in this paper rather than the similar terms "task structure" (Doyle, 1979) and "participant structure" (Philips, 1972) since I am concerned with discourse patterns similar to those laid out by Lemke (1991), but for more traditional science classes. I do wish to point out that the term "activity" here refers to a set of interdependent actions and differs from the term "activity" often encountered in activity theory (Leont'ev, 1981). In activity theory, the German term "*Tätigkeit*" (not "*Aktivität*") is often translated into English as "activity," but Russian theorists who borrowed the word tend to mean something more like "activity setting" (Wertsch, 1981). An alternate translations of *Tätigkeit* that captures this sense better would be "occupation." Examples are school and work.

identified the same basic discourse structure as dominant, although he preferred to call it "Triadic Dialogue," or "Question-Answer-Evaluation" (Q-A-E). In such a sequence, the teacher opens with a *question* having a known answer, a student *answers*, and the teacher *evaluates* the adequacy of the answer. Moving to the next level of time scale, multiple I-R-E sequences are put together to form a "classroom lesson"—opening sequences to begin the class period, followed by topically-related sets of sequences to cover instructional material, and closing sequences that end the class period. Extending this model beyond one day, multiple class meetings can also have a structure: the typical five-day sequence at the high school described below is "Lecture-Lab-Lecture-Lab-Exam." One reason this pattern of discourse and lessons is popular is that it is well-adapted for traditional curriculum. Specifically, it suits situations in which the teacher is trying to simultaneously maintain a high degree of control in the classroom and also probe students' current understandings in order to bring them to grasp a set of clearly specified concepts. But it also has a cultural dimension that goes beyond its attractiveness from a purely utilitarian standpoint.

Consider the task of teachers and students in a class making use of this dominant activity structure from a sociocultural standpoint (e.g., Cole, 1996; Leont'ev, 1981; Vygotsky, 1978; Wertsch, 1991, 1997). The activity structure of I-R-E can be seen as a "cultural tool" (Wertsch, 1991, 1997) that is familiar to most students after a couple of years in school, and familiar to teachers from their own childhoods. Thus, both teachers and students understand well the "rules" of the "language game" (Wittgenstein, 1967) they are playing in interaction with one another: they know what sorts of roles they are expected to play, what sorts of nuances indicate departure from the norm, and generally how one succeeds at participation.

Contrast the situation of participants in a classroom utilizing the I-R-E cultural tool to that of settings where students conduct open-ended project inquiry such as that advocated by Dewey (e.g., 1902, 1938). Since Dewey, there has been periodic interest in having students learn science by doing science (e.g., reforms of the 1960s beginning with Bruner, 1963). Recently, project-based pedagogy has been revived as a learning by doing teaching strategy which can promote students' active engagement with science (e.g., Pea, 1993; Ruopp, Gal, Drayton, & Pfister, 1993). Interaction in project-based classes is difficult to base on the cultural tool of I-R-E, because I-R-E does not have appropriate "affordances" (Norman, 1988). Specifically, the I-R-E method assumes that the teacher initiates interaction sequences with a question for which he or she has a known answer; in open-ended projects, however, actions are privileged over abstract concepts, and there is not usually one correct path for action. Since the project approach is still relatively uncommon, teachers and their students do not have an obvious set of well-established cultural tools to structure their interaction. This fact can undermine the teachers' priority of maintaining order, as well as the students' priority of getting optimal grades, because how students should perform to achieve a good grade is highly ambiguous, and their perceived risk of failure correspondingly high. Dewey himself warned that "the mechanics of school organization and administration" (Dewey, 1901, p. 337) often doomed reforms, but his warning did not prevent such factors from affecting his own efforts.

Within the domain of reading instruction, the "reciprocal teaching" (Palincsar & Brown, 1984) activity structure has been a highly successful means of introducing students and teachers to a new set of cultural tools for structuring their interaction. Adaptations of "reciprocal teaching" have even been implemented effectively in settings outside of school such as after school clubs (Cole, 1996). But activity structures for open-ended project inquiry are few and far between. In this paper, I will describe an activity structure developed and implemented by a science teacher for his project-based class, which has strong potential for general utility in project-based science instruction. I will also describe issues of adapting that structure to project-based *history* learning in an *after* school setting, in order to consider how adaptable the activity structure is across very different activity settings (Leont'ev, 1981) or scenes (Wertsch, 1997).

Methods and data sources

For the balance of this paper, I will be discussing activity structures in one science classroom and two after-school history clubs.

The episodes related from the science classroom are part of a larger interpretive case study (Polman, 1997) conducted from 1994 through 1996 in Rory Wagner's[2] class, as part of both of our involvement in the Learning through Collaborative Visualization (CoVis) project (Pea, 1993). The term *interpretive* is based on Erickson (1986) and refers to any form of participant observational research that is centrally concerned with the role of meaning in social life, enacted in local situations. One of the central features of the class was that students conduct earth science projects *of their own design;* what this meant in practice was that they participated in the formulation of a research question, the gathering of data to provide empirical evidence for addressing the question, analysis of those data, and reporting in both written and oral format. I was a participant observer in Rory Wagner's high school classroom for three years—one and a half years acting as a technical assistant, and one and a half years conducting the formal study (1994-95 through winter 1995-96). Data collection techniques included written field notes and videotapes of classroom observation at each project phase, collection of artifacts created by the teacher and students, and formal and informal interviews of both the teacher and selected students. Formal interviews were recorded with audiotape and transcribed, while informal interviews were

[2]At his request, Rory Wagner's real name is used. All students' names are pseudonyms.

recorded with hand-written notes. For this study, these data are being used to uncover the ways activity structures scaffolded students' accomplishment of projects.

The after-school clubs reported on here began in the fall of 1997 as part of a research project and educational intervention called HistoryWeb St. Louis, which I am conducting with James V. Wertsch. Briefly, our clubs offer participating children from grades four through eight the opportunity to develop computer-based hypermedia museum exhibits about history. The children learn about the history of the Underground Railroad, focusing on local issues, and develop Web pages that are posted on the Internet and eventually at a local museum. The interpretive case study method is being used again, with similar data collection techniques. Results from this site are preliminary, and I will focus primarily on the theoretical issue of adapting activity structures to this new setting.

The science project activity structure

After a quarter-long "lecture tour" of the earth sciences, Rory Wagner commences project work in his class. He passes out two handouts, the first of which is "How to Do an Earth Science Project." Instead of reading aloud what he has written about doing projects, Rory focuses the students' attention on some of the main issues. He reminds them, "what we're trying to do is really *do science* . . . . Instead of pretending that we're doing science by doing little lab experiments that duplicate things that have already been done by a lot of people, we're gonna try and do some things that are maybe new. Maybe things that people haven't looked at."

To give the students an idea of what he is talking about, he describes an example of a good project. The students who did the project first decided on volcanoes, and then specifically eruptions of the volcanoes, which was a good idea because "people write down when they occur." They then decided to focus on a small subset of volcanoes, specifically one type, and look for patterns in the time elapsed between eruptions. He stresses that "they looked at ... a big problem, and then kept narrowing it down until it was something that they actually could do," while he stretches his hands out wide and then brings them together. He contrasts the narrowness and tractability of the volcano project to another project, where the students said, "We're gonna try and predict the effect of global warming of the earth's atmosphere on the population in the next century." Such projects are "way too unmanageable," says Rory, even though they can sound appealing. The key is focusing them down. The students aren't on their own in figuring out whether their projects are focused enough "to be doable"; Rory is available at any time to help them. Rory then briefly describes another example project on "which group of dinosaurs lived longer, the carnivores or the herbivores?"

The second of the two handouts is "Project Milestones and Due Dates." The milestones he distributes for this second quarter of 1995-96 are as follows: (1) Group and Topic—3 days, (2) Background Information—2 weeks, (3) Research Proposal—1 week, (4) Data Collection—2 weeks, (5) Data Analysis—1 week, (6) Complete Research Paper—1 week, and (7) Presentation—1 week. Rory tells the students the reason for the milestones is his experience from the past. He says,

> I realized a couple of years ago when I started doing this, that I couldn't just say, "OK, let's go out and do research, and the week after Christmas your paper will be due, go for it." Because what will happen is, everybody will sit here and play video games, and talk, and chat, and then over Christmas break a couple of you will get together and start working on it, and then that week before it's due everybody will say, "Wait! we don't have enough time. We can't get it done." Whatever. It's procrastination to its nth degree. And we know that happens because that's human nature.

The series of milestones Rory has laid out are different from the recipe-like labs students may have conducted in other science classes, though. Traditional lab steps give such detailed directions for every step that students can almost blindly follow them and "get the right results." Rory's milestones, on the other hand, provide a framework that breaks the multiweek project activity down into more manageable steps. But the exact steps each student group will follow is not determined beforehand. There are no "right answers" in the sense that many traditional labs have right answers. Instead, there are multiple paths that students could follow to reach well-reasoned empirical conclusions about topics in earth science. Along the steps of these paths, they turn in intermediate written artifacts that require them to "use complex thought" (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991) rather than the more trivial fill-in-the-blanks and prompted questions found in traditional labs. Additionally, traditional labs involve the whole class in the same lockstep activity, whereas Rory's students work on different problems of their own design and choosing. In order to understand how the framework of milestones helps to structure student participation, I will describe a project that makes effective use of Rory's activity structure. Part of the effective use of this activity structure is the way it provides multiple occasions for Rory to give feedback to students on their work so far and suggestions for their next steps.

Choosing project partners

TJ and Dave are two experienced seniors sitting in the back right corner of the room with their friends Amy and Julie. TJ is a stocky lacrosse player with long brown hair, and Dave is a somewhat slighter hockey player with short hair. They are wearing one variation of their standard attire: TJ in jeans and a sweatshirt, and Dave in jeans and a casual crew shirt. As usual, their eyes are nearly obscured by ragged baseball caps with college logos. Right after Rory's presentation and discussion about how to do a project, they decide to work together on their project.

Choosing a topic

After choosing partners, Dave and TJ have to choose their topic. On the first day of projects, Rory told the students, "You gotta figure something out that you want to study. It can be a lot of different things . . . it should be something that you're interested in." Besides being something they're interested in, their topic must be part of earth science. One student had asked whether earth science included diseases, so Rory described some rules of thumb for what their research could include,

> . . . anything that's in an earth science textbook. So that's basically everything that we've talked about already, plus anything else that you'd find in there, or in . . . any of those sciences that interests you. We talked about astronomy, meteorology, oceanography, and geology. We talked about mountains, and volcanoes, and plate tectonics. We talked about stars, and planets, and galaxies. We talked about oceans, and currents. And we talked about storms and weather patterns and climate. And so, all of that stuff would be project topic material. A general guideline that I use, pretty cut and dried: if whatever you want to study is alive, it's probably *not* an earth science topic. It it's dead, or never been alive, it probably *is* an earth science topic. But you need to have it—you need to clear it with me in the first place.

For their project topic, TJ and Dave choose hurricanes. They had begun thinking about what they might want to do for a project when Rory was giving some of his final lectures, and had latched onto hurricanes during the weather lecture. When I ask them what interests them about hurricanes, TJ says, "the destruction, to be honest. We also wanted to know how they fly into the storm. That's how they track them, you know."

Right away, they begin a pattern of turning in Rory's assignments in a timely fashion, by sending their topic to Rory by email a day early. They had noticed Rory's comment that they get bonus points for turning in milestones early. When I ask them on Friday, the second day, how it's going, they tell me, "We're doing hurricanes. We emailed it to him—we got our 10 points." Although they find out later Rory only gives bonus points for turning in the last four milestones early, their enthusiasm serves them well.

Background preparation: Learning about the topic

Dave and TJ spend the first two weeks of the project diligently reading books about weather and hurricanes so they can learn more about their chosen topic of "patterns and destruction of hurricains [sic]." On the first day of projects, Rory had told the students,

> After you get a partner, and after you get a general topic, then you have to do background research. That's where you start finding out all you can about the information, on your particular topic. OK? So let's say you pick volcanoes. What you do is read everything you can about volcanoes. I generally would like you to start in your textbook. Read everything you can in the textbook. Then, find other geology books, whether they're on the shelf over

> here, or I have a whole stack of books next door. Find all the stuff on volcanoes. Read it, so that you know how volcanoes work: where they are, why they erupt, why they don't erupt. Everything that you can. You have to become a miniexpert on volcanoes. That's your background research . . . . You need to turn that in, then, when you're done with that, in approximately two weeks.

They borrow the books from Rory's collection in the classroom, and also begin to track down some hurricane resources on the Internet. They ask Rory to help them save an image showing hurricane paths they find on a Web site, and they include the image in their Background Information report they turn in a day early during the second week. Their report contains a descriptive overview of what hurricanes are, how they arise, and the destruction they cause, synthesized from the reading they have done. As an exemplary piece of what Rory terms "traditional library research" their background information report earns the pair an A+.

Interlude one: The development of milestones and the paper format

Up until this point, TJ and Dave's work, like that of the other students in the class, has been for the most part "traditional," with the possible exception of adding Internet research to the traditional library research[3]. As he mentioned on the first day, Rory has broken the long-term process of conducting science projects into a series of interim milestones that provide a "framework for [students] to work in," after seeing his students flounder in 1993 when faced with ten-plus weeks and a paper to turn in at the end. Dave and TJ are the beneficiaries of a set of initial milestones Rory has refined over the past few years, and it is worth reviewing the development of the milestone assignments.

The original milestones Rory laid out in the spring of 1994 to getting the project done were: (1) choosing a research question; (2) doing background research on the question; (3) finding or collecting data that would answer the question; (4) analyzing the data; and (5) writing up the final paper. He encountered one major problem with these steps immediately. He found that students with little previous background were simply unable to come up with much beyond what Scardamalia and Bereiter (1991) term "basic information questions," such as one young woman's query, "why does a comet revolve around the sun?" In order to come up with more ultimately productive "wonderment questions" such as her group's eventual "how does a comet's core size affect its tail size?" students need a little more background on the topic area than they typically have. This is particularly crucial since Rory also found that one of the "critical" parts of doing a science research project is that you "have to come up with a question that you can work on," or

[3]Rory Wagner's classroom is equipped with six Macintosh computers with Internet capabilities. As part of the first quarter's activities, students learned to make use of the World Wide Web, electronic mail, and Usenet newsgoups related to science. The integration of project science pedagogy with Internet technology is a major aspect of the CoVis project.

else you will not get far. Therefore, Rory adjusted the milestones for the 1994-95 year such that Step (1) did not include deciding on a research question, but instead a general topic area which students then have time to read up on and, if necessary, learn more about. *Then* they could come up with a focused research question by brainstorming.

But for the first project in 1994-95, students did not turn in Background Information *reports* such as the one Dave and TJ did. Later in that year, Rory added the report as a formal milestone to focus the initial period of learning about the chosen topic area, rather than relying on informally giving the students time to learn about their topic. The Background Information milestone simultaneously serves three purposes: (1) it gives students an interim goal around which to focus their background reading and research on their topic; (2) it lets students apply the familiar model of "library research" or synthesis of established descriptions of a phenomena (which they may have learned in other classes, especially English and history); and (3) it makes explicit the fact that they must go on to do something different in subsequent milestones and the final report and presentation. Too often in previous years, Rory saw students get bogged down gathering and synthesizing information about their topic—whether it was from books, journals, or the Internet—and they ended up with final reports that synthesized that information. Synthesis of known information is what Dave and TJ have done to this point in their project, and they've done it well. On the first day of the project, Rory told the students,

> You know, in a lot of papers, . . . you'd be done after [the "background information" milestone], basically . . . . But that's what's different about science. Because, you know, you don't just take all the information you can find from all the different sources, and like, cut and paste and put them all together, and say, "Voila! Here's everything that I know." That's part of it.

There's more, though. Now Rory wants them to move beyond that step to carry out original empirical research. They will examine data to answer a research question they formulate, with his help.

> Once you know a lot . . . about a topic, you then need to focus it down—just like I gave you that example with those kids with volcanoes—into something that you actually can do some research on. Something where either you can do an experiment, or look for data that somebody else has collected, to try and answer a particular question that you have.
> So that's [the next] step: "narrow your broad topic down into a research proposal." I think this is a very hard step. Up until this time, everything is pretty easy and straightforward. This *can* become kind of complicated. How to whittle that down—you know, it's like taking a tree trunk and trying to whittle it down into a toothpick. It takes a while sometimes. OK?

Brainstorming and refining research questions

Since this whittling down to a research proposal would be so difficult, Rory had tried to come up with ways to give the students more support. At the beginning of this year, Rory decided he wanted to try brainstorming research questions and proposals with the class as a group. He was at first not sure when to hold the session, but decided to hold it when all the groups were about to put their research proposals together, after the Background Information was returned. He figured that would provide for optimal participation and interest, since the discussion should help the students get in their next milestone (the Research Proposal). So on the Monday after the Background Information was due, Rory gathers the class together, saying,

> Remember, our next deadline is Friday. You need to have a workable, doable, researchable, very specific question based on your topic. This is, this—I see three critical parts, basically, to doing projects, doing science—one is that you have to come up with a question that you can work on. Then you have to find the data. And then you have to analyze that data to get an answer. So those are the three parts, and once you do those three parts, then everything else is kinda like, you know, the dressing. It just kind of all fills in around there.

He then holds a whole class brainstorming session on research questions, using a photograph of a wolf pack from his office. He asks the class "what are some questions that come to mind" based on the photo. After the class generates a number of questions, many of which are basic, he asks them to choose a question to pursue further. They follow several questions further, and he helps them to see that many of their broad suggestions would be difficult to address with accessible, numeric data, and they need to be more specific. When one student mentions sizes of packs, he latches onto it, and suggests the even more specific "what is the average size, or the size distribution of wolf packs in Minnesota?" Some students wonder, "How do we write a six-page paper on that? What is there to write?" But they discuss what data they would need to answer this question, and how they could construct a research report on it. He describes a possible report in detail, based on the outline he has distributed. The students seem somewhat reassured, but one asks, "What if you get all the information you can, but you have like a lousy question?"

Rory tells them, "I'm gonna try and not let you down the wrong path to start with." He also warns students they will run into trouble if they "have a good question, but can't find the information [to answer] it." If they figure that out soon enough, they can try to adjust their question to a more manageable one. But "in the very worst case scenario, you absolutely can't find anything, you can't turn anything into something, you can still report on what you did. That's still a scientific investigation, and that's still valid. Even if you don't find an answer."

In the end, Rory asks the students,

> I want you to continue to do this with your own projects. This is your job. This is your deadline for Friday. To ask questions about your own project, and then continue asking questions about all your own questions, and seeing—trying to write down. Try and keep it all on one sheet of paper, so it doesn't get lost. Questions about questions, or what information you would need to answer any one of those questions.
> And then, keep in mind that you want to come up with a very focused, a very focused kind of a question at the end of this process.

By the next day, TJ and Dave have generated a list of questions, which they show to Rory. A short discussion ensues:

> **Rory:** You've got some good things here. "What are the patterns?" is a good one. Like, what are the patterns over time?
> **Dave:** Yeah, there are hurricanes every year, but this year it seems like there's more.
> **Rory:** And why is that? You could look at how many there were every year, and it might expand to how many at what time of year. What about the sizes of them over time, or in any particular season? . . . For starters, I'd say the patterns one is the best, and also this one [about size] is kind of related, but if one of the others is related, it could become relevant too.
> **Dave:** OK
> **Rory:** I hope I helped

At about this same time, Rory assigns Dave and TJ a mentor, a university-based scientist who specializes in atmospheric science and climate. Rory asks the student groups to introduce themselves to the scientists by email. Dave and TJ get a response from their mentor within a day, and Dave asks Rory, "Do we have the Web?" Rory explains that "the Web" is what they are looking at when they are using Netscape, so they do have it. After Dave and TJ tell their mentor they have access to the Web, he sends them a number of library book references as well as Web site addresses about hurricanes. TJ and Dave explore the Web pages he tells them about[4], and they follow links from these pages to other hurricane sites. Eventually they find a historical dataset of yearly hurricane activity from 1880 through 1995, at http://thunder.atms.purdue.edu/hurricane.html. Dave and TJ are excited about all the maps and pictures they have found, which show, among other things the paths hurricanes have taken in the Northern Hemisphere. So, they decide to propose a research question on the paths. Specifically, they propose answering "Is there a preferred pattern of hurricane movement in the Northern Hemisphere?" They propose gathering data from the Web site over a period of years to establish the patterns. At the end of week three, TJ and Dave's proposal is approved by Rory, which is not surprising, since he collaborated in its construction. The students generated the initial idea of examining "patterns" of hurricanes after the brainstorming session and their Background Information report; Rory liked the idea and added the prospect at looking for patterns over some period of time; and the students refined their idea to focusing on the

[4]If you are interested in exploring these web pages yourself, the addresses are http://banzai.neosoft.com/citylink/blake/tropical.html, http://www.station.net/~kenf/tcc.html, and http://www.nhc.noaa.gov/.

patterns of hurricane *movement*, after finding images showing the paths of hurricanes with the help of their mentor.

Stepping back: Discourse sequences to replace I-R-E in projects

At this juncture, I'd like to step back again from the details of this case to delineate the activity structures for project-based inquiry which Rory uses to replace the traditional format of classroom lessons and discourse described in the introduction. In some ways, Rory's milestones are the equivalent of Mehan's opening, instructional, and closing phases of a single classroom lesson. The big difference is that the milestones stretch over a period of weeks instead of forty minutes. But what is the equivalent of Initiation-Reply-Evaluation? I propose two common interaction sequences: [Framing]-Question-Clarification, which is very short, and [Framing]-Bid-Negotiation-Instantiation-Evaluation, which extends over time. All of the interactions that take place within projects such as Dave and TJ's are understood in relation to the *framing* of the activity, which Mr. Wagner did on the first day of projects, and which continues to be refined through discussion and reference to the milestones over time; thus, the framing step is often implicit or prior in time to a concrete interaction. Unlike I-R-E, interactions are most often initiated by students, either in the form of a question about projects or a bid for a workable action path. An example of a Q-C interaction is the one above between Rory and Dave, where the student asks the question, "Do we have the Web?" and the teacher clarifies the terminology Dave had forgotten. An example of a B-N-I-E interaction is begun above, when the students present Rory with a set of *bids* for possible future action in the form of proposed research questions. He and the students *negotiate* both the meaning of their bids and their possible consequences for future action, with both students and teacher potentially contributing important details. Sometimes this negotiation is much like Donald Schön's (1982) description of design professionals' "frame experiments," and it always results in a decision on a path for next steps. Next, the students will *instantiate* their understanding of the agreed upon path, after which the teacher will *evaluate* what they have done. The evaluation often leads to new suggestions or requests for bids from Rory, based on what he has seen, and the process repeats. Note that either the students or the teacher can take the Bid Step, all are expected to participate in the Negotiation Step, the students are responsible for the Implementation Step, and the teacher for the Evaluation Step.

Data collection and analysis

After agreeing on a research proposal, Rory had told the students they need to "figure out where to get the information" they need. Like some other students, Dave and TJ figured out where their data would come from while deciding on their proposal, so they move directly into the next phase of the project, which is gathering the information and data they need to answer their question.

Over the next two weeks, TJ and Dave work diligently to gather hurricane data off the Web. Rory tells me early in week four, "I have a gut feeling they don't know what they're looking for. They think it's a 5-minute process or they already have it." But Rory holds back, and lets them see for themselves what it takes to work with the images that show hurricane paths. It takes them a while to download images for a set of years, and they learn how to manipulate the images in graphics programs so that they can change the background color from black to white. They turn in a set of data just before the end of week five, and as they begin their data analysis, they realize they need to find a way to compare the paths on more than one image. TJ comes up with the idea of tracing hurricane paths by hand off the computer screen onto transparencies, which can be laid on top of one another. Now that they have gathered a body of data, Rory challenges them to go on to the next step of the project, figuring out "what the data says." The image of "talking with your data" comes from Rory's masters advisor. About his masters project, Rory told me,

> [data analysis] is hard, though, for all of us. It reminds me of my masters advisor, who was a petrologist. We worked with igneous rocks, and the rocks became your data. He said, in his smiling brown face, "You have to talk to the rocks and the rocks will talk back to you." You have to poke it, sift it, organize it, and it'll talk back to you.

Through the processes of "poking, sifting, and organizing" all these images and tracing their paths, the students have gotten a definite impression of what the data says about how hurricane paths tend to be shaped. In an interview outside of class, Dave tells me,

> We really are finding mainly that most of them are starting in a . . . [they] start southeast of Florida and east of the Caribbean, and then kind of like they're really making a swoop up towards the United States, and then they die in the Atlantic. They make a little semicircle.

When I ask him to show me on paper how the hurricanes tend to move, he draws the following:

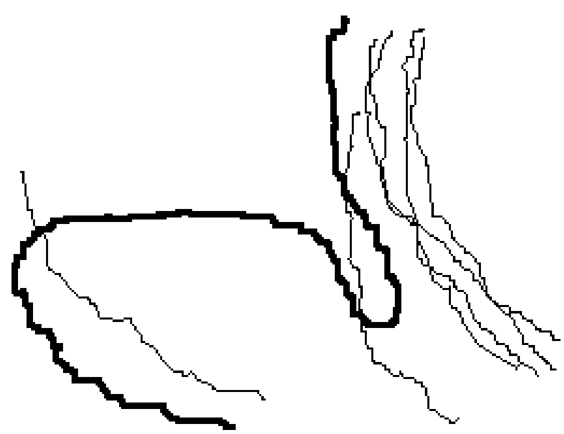

Figure 1: Dave's drawing of common hurricane paths

As he is drawing, Dave explains,

> . . . They kind of like start here [southeast of Florida], and then they kinda swoop like that [along the East coast]. You know, and then some of them occasionally, you know [draws one going over Florida, and one into Texas/Louisiana].
> Joe: Right, those are the ones that blast over there.
> Dave: Some—that's like the general, you know
> Joe: Oh. And so there always doing that [I draw a "C"-shape swooping from southeast to northwest to northeast]
> Dave: Pretty much, yeah.
> Joe: And there's more of them over here [in Atlantic off coast]
> Dave: Yeah, and generally some—you know, we've had a couple that have hit Texas, and some have gone up the coast of Mexico.

However, figuring out how to turn this general impression into an analysis of data proves difficult for Dave and TJ, just as it does for most of the rest of the class. For their data analysis milestone due at the end of week 6, TJ and Dave turn in four separate maps of hurricane paths for 1899 and 1993-1995, in electronic form and traced on transparencies. They just barely get the assignment together by the end of class on the due date, and hurriedly compose an ad hoc "conclusion" in the email message to which they attach the map images. Rory is unsatisfied with their use of the data to support conclusions. He tells me afterward,

> I asked them why they picked those [years], and they said, "we thought we would compare average years."
> So I said to them, "how do you define average years?" I was trying not to shoot them down, so I asked them "How did you figure out they were average years?"
> "We looked at maps"
> "You have to prove it to me, or the reader, that these are average years. You can't just say it. You can say you have 4 apples, but if 3 are red and one is green, you have to convince me they are all apples . . . . "
> How do you define the average year? Maybe with frequency? Someone in another class is looking at the number of hurricanes per year. There's also the number of storms, tropical storms, and the number of each hurricane category . . . . There were 21 hurricanes last year. Other years had 5, 8, 10, and 11 . . . . But maybe the average is not in terms of numbers, maybe it's in terms of paths. Maybe you can see which years are average, then use those . . . .

Rory sees TJ and Dave's picking so-called "average" years based on no explicit criterion as an example of "generalizing a conclusion from inspection" of data. In this conversation, he pushes the students to not make claims, such as TJ and Dave's contention that the years they chose were "average," unless they can back them up with reference to the data. When he generates the two possibilities that average years could be determined by the *number* of hurricanes or by the *paths*, separated by the qualifier "but maybe," Rory is also modeling the scientific practice of generating alternative hypotheses with means of disconfirming each. In this case the discussion does not lead to further analysis of what constitutes an "average year," however, since that is not the main thrust of their project. Instead, the students concede the point that their sampling procedure of discontinuous years is questionable, so they need an alternative strategy that they can act on with only a week to put together their complete research report. So Rory makes a suggestion: "Why not twist the project to the last 10 years, so you could use 3 you've done already?" On this advice, TJ and Dave use the sample from 1985 through 1995 (which they later realize is eleven years).

Putting it all together in the research report

As Rory mentioned on the first day of projects, the next step is putting together the research paper. He tells the students,

> Once you've done data analysis—you should have a pretty good idea of what your question is, and what the answer is—then you can write your paper. Actually, what you're going to be doing, is, you're going to be assembling parts of your paper as you go along. So it's not like, "OK, I'm gonna do all this work, *then* I have to start writing the paper." This is actually designed for you to do parts of your paper as we go along, and by the time you get to [writing the paper], it's basically just finishing things up. It's analyzing, it's putting things into final form.

Rory has designed the milestone assignments for the project so that they correspond to sections of the written research report. Students' written milestones thus serve as first drafts they can revise and combine to create a draft of their final report. Table 1 shows what milestone assignments correspond to sections of the paper.

Milestone	**Research Report Sections**
Broad topics and partners	
Background Information	Introduction
Research Proposal/Question	Method (expanded)
Data Collection	Results, part A
Data Analysis	Results, part B, and Conclusion
Paper	(Combine above, expand where necessary, and precede by Abstract)

Table 1: Correspondence of milestones to report sections

The design of project activities that Rory has developed for his class is powerful in part because of the synergy between the activity structure embodied in the milestone assignments and the "artifact structure" embodied in the format for the written report. Like all activity structures, there are dependencies between the parts. Some of the interdependence between parts of the activity, as well as the support Rory provides throughout the activity, is mediated by these interim written artifacts. The milestone artifacts are "shared, critiquable externalizations of student knowledge"

(Blumenfeld, *et al.*, 1991; Guzdial, 1995) that Rory uses as occasions for feedback. Recalling the sequence of [Framing]-Bid-Negotiation-Implementation-Evaluation detailed above, this broad activity structure ensures that students will complete multiple cycles of the sequence. Each milestone after choosing partners is a written "Implementation" step, which leads Rory to suggest or request new bids that can be naturally incorporated into the final milestones of paper and presentation. If each milestone were a free-standing separate assignment, on the other hand, the usefulness of the teacher's feedback would be of less concrete use. The activity structure "works" as a system in this abstract sense, but is nonetheless new and at times difficult for the students to carry out, as becomes apparent at this juncture in the hurricanes project.

After TJ and Dave download the remaining images for each year from the Web, they trace them onto transparencies. In an effort to get an overview of all the data, they create a composite image showing all the hurricane paths from 1985-1995. The students and Rory come to refer to this representation of all the paths together as a "spaghetti bowl"—there is so much data covering other data in the image that it is difficult to make sense of the whole thing. At this point in the project, TJ and Dave have to figure out how to put their burgeoning knowledge of hurricanes, and their impressions of hurricane paths into a coherent, written report, with conclusions supported by data analysis. The process proves difficult for TJ and Dave, just as it does for most of Rory's students.

On Thursday during Week 7, with a day to go before the research report is due, Dave and TJ have a long conversation trying to solidify data analysis techniques. Rory asks them what the general pattern of hurricanes is, and TJ shows him the "C" shape Dave had described to me previously (see Figure 1 above). Rory suggests they think about where the hurricanes occurred—they could define the rectangular area that defined the boundaries of the hurricane paths. Borrowing inspiration from the constituent mineral analysis Rory had done as part of his masters in Geology, he also suggests the possibility of dividing the map up into cells of equal space on a grid. Then, they could count up frequencies of the hurricane paths through each cell of the grid, to see where the highest "hazard potentials" were for the 10-year period. As they continue to look over the "spaghetti bowl" of data, Rory notices that not all the hurricanes follow the "C"-shaped path Dave and TJ had described. Some are straighter than the standard C, and others appear erratic. He then suggests they could devise a categorization scheme for the shapes of paths. They could go back to each year and put a morphological name on each hurricane, count up the frequencies of each shape, and calculate the percentages. He tells them he believes that analysis would be "valuable."

The conversation about data analysis was extremely productive, and Rory is excited about it. He tells me after class, "there are a lot of things you could squeeze out of what they did instead of just the paths." The only problem is, "the conversation [he] had with them . . . should have taken place last week. It generated more ideas, but there [is] no more time." Not surprisingly, Dave and TJ's incorporation of these ideas is only cursory in the report they turn in on time the next day. Like most of the other reports, Rory finds Dave and TJ's report riddled with problems.

Revising the paper

Rory returns bleary-eyed the following Tuesday, after a long weekend, and announces to me,

> I was up 'til 2:00 a.m. last night working on this. It's really hard to figure out what they meant. They get into this verbiage where they're trying to sound like they know what they're doing, but it doesn't make sense. Maybe they knew what they meant, but it's not clear.
> Today is damage control day. They're gonna get these back, and say, "geez, I can't believe this. I worked hard on this and thought I did a good job, and look at my grade." For example, the hurricane group got a 51%, and it's a great project . . . .
> The whole schedule is revised now. I can't make them do [presentations] on Friday. They need to revise this work . . . . Presentations will then have to be in the second semester ... Almost across the board there was no Method or incorrect Method. They have to fix it up. They'll have until finals to turn in a revised draft . . . then a week of creating presentations, and then the following week to give them . . . .

In his extensive commentaries written on the paper, Rory tries to be encouraging. On the front page, he begins with "Outstanding Effort! Don't quit now!" He tells them the "good things" are that they have "excellent data collection and manipulation," but the "bad things" are (1) "No Method," (2) "Data Analysis extremely weak—but fixable!," and (3) "can't support Conclusion from the Data Analysis." These major problems, compounded by a few minor formatting issues, have resulted in the low grade of 51% (the highest grade in the class was 64% on this draft). The neglected Methods section was not merely an oversight. TJ and Dave are clearly unfamiliar with certain aspects of the scientific research report writing genre, as exemplified in the conversation which ensues during class. For instance, they don't know what the "Abstract" and "Method" sections are, and how they differ:

> **TJ:** So is the Method, you just recount everything, how you've done things?
> **Rory:** How you did what you did. How you did what you did, and what you did.
> **TJ:** I thought that was the Abstract.
> **Rory:** No, the Abstract . . . .
> **Julie:** It's a summary of that.
> **Rory:** What she said.

The group's statements in their Data Analysis are still not supported well by the data. Rory's comments on this section of their paper begin, "You have lots of good data to analyze. But you just packaged all the data into a pile, saying, 'here it is,' and you made statements in this analysis section *without* referring to the data once. You *can't* do that." He points out specific examples. TJ and Dave had written, "We found that most of the recorded storms began in the Atlantic Ocean, east of the Caribbean and made a C-like shape towards the United States and finished back east of the northern United States." Rory comments,

> In *this* statement, you need to *show/prove* this is true. Which diagrams show this? Of the total number of storms over this 11-year period, exactly how many (and then, what %) of the storms had this "C-shape" path? You need to show, in step-by-step fashion, how you came up with your Conclusions/Results. *Back up* what you say with your graphs.

After these comments, Rory proceeds to expand in writing on the various analysis strategies they had begun to flesh out together during class the previous week. First of all, how they could classify each storm in the time period as having one of a set of path shapes, such as the C-shape they mentioned. He points out that a complete analysis of "hurricane paths" also include issues of location and not just shape: where the storms begin and end, perhaps where they turn if they turn, what the boundaries of the "spaghetti bowl" of storms are, and how often each cell in a grid dividing the total area was hit by a storm. Rory ends by writing, "Bottom Line: Lots of ideas, late in the game. Which ones are 'doable' in the available time? You decide."

For their revised report, the boys carry out many of Rory's suggestions. They categorize each storm as having one of three path shapes, and give the number of storms within each category among the 83 storms over the period. They also produce a pie chart showing the percentages of each shape (see Figure 2).

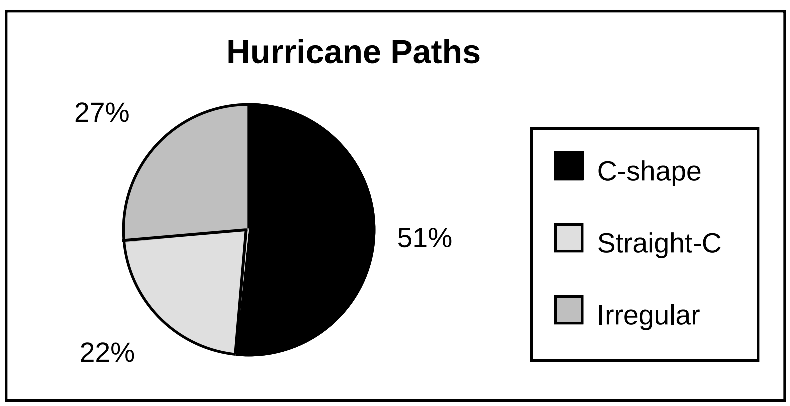

Figure 2: Pie chart of hurricane path shapes, from revised report

The hurricane group's revised report is a significant improvement over their first draft, with a Methods section and conclusions supported specifically by data analysis. The improvement is reflected in a revised grade of 91%.

Final presentation

The final phase of the project is the presentation. As Rory told the class the first day of projects, "Each group has to do an oral presentation to the class, telling the class what they did, and what they found." During the following week, Rory gives a sample project presentation using Microsoft Powerpoint viewed on the overhead televisions. Dave and TJ become excited about the program and ask Rory if they can borrow the program over the weekend to work on it. They complete an impressive series of slides explaining their research over the weekend and finish their first project pleased with all they have learned. Dave says they learned "a lot about hurricanes . . . I mean, just, all this time that you've been working . . . you get that much time to do your topic . . . and when you come to your presentation, it's just second nature. I mean, you just really know what you are talking about. I mean, I felt real confident." He thinks he learned more than he would in a traditional class because "you're doing stuff that you really wanna do and that you really wanna learn about." They also learned along the way about computer tools like Powerpoint and the Internet. He says, "Coming in here I had no experience [on email and the Net]. I mean, I feel like an expert now." He feels this has happened because "we do it so much" and "you just learn stuff, doing—like, when you're actually doing stuff so much better than really trying to memorize how to do stuff."

By guiding Dave and TJ through the activity structure he's designed for conducting projects in the classroom, Rory creates occasions for the students to "learn by doing." As Dave said, "he leads us into whatever we have to do very nicely." And along the way, Rory acts as a resource and facilitator as needed:

> Whenever we, you know, got into a jam, and it seems like . . . he always has a solution, or an example, or something new to do. Like, in our papers . . . he knew we could make 'em better, and so he, you know, let us all redo 'em. And each page, you know, was just filled with more ideas. I mean, which kids would think are probably—you know, that's annoying, bad. But, I mean, we—from our first draft to our second, it was—we made such an improvement. Just from all of his comments, and explaining everything. It really helped, I think. I mean, I think it's definitely one of his strengths, it seems like he can solve any—answer anything that comes up. I guess that's one of his strengths.

Now that we have seen how this activity structure operates in a high school earth science classroom, let's turn to issues of adapting the structure across settings.

Challenges of changing scenes

After I completed my research in the project-based science classroom, I hoped that I could take part of what I learned about the workings of Mr. Wagner's activity structures and apply it to the new settings in which I would be working, after-school "HistoryWeb" clubs. As mentioned previously, the after-school clubs challenge younger children to conduct local history research, culminating in the development of computer-based museum exhibits. I saw certain similarities between the activities taking place in the two settings. Specifically, both involved open-ended, long-term research projects, a commitment to social constructivist learning principles, and the production of concrete artifacts. But there were many differences as well, such as the research discipline (science vs. history), the task (graded papers and presentations vs. ungraded web pages), and the setting (formal school course with mandatory attendance vs. informal club with optional attendance).

In order to systematically look at the differences between what would be going on in the two settings, I considered using Leont'ev's (1981) framework for perspectives of analysis in activity theory. He describes three perspectives, which have dialectical tensions across them: (1) the activity setting, which is associated with certain motives, (2) the action, which is associated with certain goals, and (3) the operations, which are associated with certain conditions. Although this avenue seemed promising, I decided instead to follow James Wertsch's (1997) recent use of Kenneth Burke's (1969) "pentad" of perspectives for analyzing human action and motives: "what was done (act), when or where it was done (scene), who did it (agent), how he did it (agency), and why (purpose)" (Burke, 1969, p. xv, cited in Wertsch, 1997). Table 1 below shows the two settings and projects according to these five categories:

	Project-based science class	**HistoryWeb after school club**
Scene (when/where)	Earth Science class/classroom	After school club/school library
Act (what)	Open ended research leading to empirical science report	Open ended research leading to history and personal web pages
Agent (who)	Students & teacher	Children, leader & "big siblings"
Agency (how)	Talk, writing, Internet tools, numeric analysis and IMRD paper	Talk, writing, Internet tools, historical analysis and storytelling
Purpose (why)	Grades, learning	Fun, passing time, growing interests, learning, plus web pages?

Table 1: Differences in projects across Burke's pentad of perspectives

Clearly, there are important differences across all these levels. The possibility of using the two activity structures described for the project-based science class (milestones and the B-N-I-E sequence) in the other setting are affected by differences at several levels.

The milestone activity structure is the more difficult to adapt for the after-school history club, primarily because the nature of the *act* and the *agency* in each setting is tied to the respective disciplines of science and history. Mr. Wagner's milestone activity structure is designed to correspond to portions of the prominent science research article genre, with its common rhetorical sequence "Introduction-Methods-Results-Discussion." In contrast, historical writing does not typically follow this rhetorical structure, and instead follows narrative organization. Although common story structures could be used for a series of milestones in some ways analogous to that used in the science classroom, the multiplicity of forms used within the broad genre of historical storytelling would make settling on one structure problematic. In addition, the Web pages that participants in the history club construct can differ significantly from traditional historical narratives, due to the capabilities of the new medium.

Despite these difficulties, the question of how one *could* adapt the milestone activity structure across activity settings makes clear that the process must involve choosing appropriate or promising analogs along the dimensions of act (what) and agency (how). If the "what" is the open-ended production of a class of material artifact, a task analysis (as is sometimes done in software design work, e.g., Drury, *et al.*, 1987) could be helpful. By breaking down the production of the sort of artifact desired (as Rory did in for the science research report), educators can specify the milestones which can serve the sorts of roles they did in the science project task. If this strategy is taken, the milestones of the task should be designed to correspond to portions of the final product, so that feedback participants receive on interim artifacts is not just retrospective. Unlike a set of isolated steps, children's milestones should be set up build upon one another *and* feed into a portion of the final product. Thus, children will be scaffolded by breaking the long task down into more manageable subgoals, each of which provides iteration of their ideas and writing for the final product.

The Bid-Negotiation-Implementation-Evaluation sequence seems to have more promising general applicability across widely differing activity settings. Nonetheless, differences in the scene and all the other elements of the pentad affect ways that this discourse sequence will be carried out. If the *scene* is an after-school club, it implies that the *agents* are not defined as students and teachers, with all the accompanying power relations and practices. Nonetheless, having adults who act as leaders and "big siblings" is appropriate. Since it is an explicitly educational after-school club, learning is understood as one of the *purposes*. But grading is rarely appropriate in an out-of-school setting. Various participants (and their parents/guardians) will likely have purposes such as having fun, passing the time in a safe environment (i.e., rather than "on the street" or in a "latchkey home"), and growing interests. But the inappropriateness of grades makes having the *act* itself be a valued *purpose* for all the participants in the club. The reason is that the "Evaluation" stage of B-N-I-E must be based on a purpose shared by the evaluator(s) and the creators of the evaluated artifact, in order to feed back in to another Bid. In the after-school club, this is one reason we chose to work on creating museum exhibits which would go on the Web[5] and into a local museum—the

[5]If you wish to see them in their current state, they are at http://ascc.artsci.wustl.edu/~educ/historyweb/

children would be likely to value the purpose of creating effective Web pages, if their artifacts were going to have real audiences[6]. In our experiences so far, this anticipation has been borne out. Once children see that the Web pages they are working on are going on the Internet, they have expressed desire to add more features, and make their work match up to the best of the other work they have seen. It has also helped to create an environment where the adults are naturally not the only evaluators—children compliment one another by mimicking compelling designs, and comment on one another's creations as you might see in a studio. If we have time, we plan on explicitly supporting children in designing evaluations of their exhibits with one another and outsiders as "users."

Regardless of the presence of a formal "evaluation" phase of club work, our preliminary experiences indicate that numerous discussions beginning with "what do you think about . . ." or "what about trying this . . . " lead to B-N-I-E sequences.

Conclusion

In this paper I have demonstrated how activity structures scaffold children's performance of complex open-ended projects. For the activity setting of a project-based earth science class, I showed how activity structures at two different time scales supported students in the accomplishment of science research. On a more long-term scale, the milestone activity structure works by taking advantage of a synergy between a small set of interim material artifacts and the portions of the artifact that is the final product (a science research report). On a shorter time scale, the repetition of Bid-Negotiation-Implementation-Evaluation many times helps the teacher to guide students in their work, while requiring that students remain active. For the activity setting of an after-school history Web club, I described how adapting the milestone activity structure across disciplines presented a number of hurdles, but the B-N-I-E discourse sequence seems generally adaptable to a wide range of inquiry-oriented work.

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[6]The fact that a real audience tends to make the "act" an intrinsically valued "purpose" may explain why so many after-school educational endeavors involve real audiences. Examples that come readily to mind are dance studios (Ball & Heath, 1993), piano lessons, drama clubs, sports, and the Boy Scouts' soap box derbies.

References

Ball, A., & Heath, S.B. (1993). Dances of identity: Finding an ethnic self in the arts. In S. B. Heath & McLaughlin, M.W. (Eds.), *Identity and inner-city youth* (pp. 69-93). New York: Teachers College Press.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., and Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist, 26*(3), 369-398.

Burke, K. (1969).

Cole, M. (1996). *Cultural psychology: A once and future discipline*. Cambridge, MA: Harvard.

Collins, A., Brown, J. S., & Newman, S. (1989). Cognitive apprenticeship: Teaching the craft of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser*. Hillsdale, NJ: Lawrence Erlbaum Press.

Cuban, L. (1984). *How teachers taught*. New York, NY: Longman.

Dewey, J. (1901). The situation as regards the course of study. *Journal of the Proceedings and Addresses of the Fortieth Annual Meeting of the National Education Association*, 332-348.

Dewey, J. (1938/1950). *Experience and education*. New York: Macmillan.

Doyle, W. (1979). Classroom tasks and students' abilities. In P. L. Peterson & Walberg, H. L. (Eds.), *Research on teaching: Concepts, findings, and implications*. Berkeley, CA: McCutcheon.

Drury, C. G., Paramore, B., Van Cott, H. P., Grey, S. M., Corlett, E. N. (1987). Task analysis. In G. Salvendy (Ed.) *Handbook of human factors* (pp. 370-401). New York: Wiley.

Erickson, F. (1986). Qualitative methods in research on teaching. In M. C. Wittrock (Ed.), *Handbook of research on teaching.* New York: Macmillan.

Guzdial, M. (1995, April). *Artifacts of learning: A perspective on students' learning processes and strategies through their learning products*. Paper presented at the Annual Meeting of the American Educational Research Association, San Francisco, CA, 1995.

Lemke, J. L. (1990). *Talking science: Language, learning, and values*. Norwood, NJ: Ablex.

Leont'ev, A. N. (1981). The problem of activity in psychology. In J. V. Wertsch (Ed.), *The problem of activity in Soviet psychology*. Armonk, NY: M. E. Sharpe.

Mehan, H. (1978). Structuring school structure. *Harvard Educational Review*, *48*(1), 32-64.

Mehan, H. (1979). *Learning lessons*. Cambridge, MA: Harvard University Press.

Mehan, H. (1980). The competent student. *Anthropology and Education Quarterly*, 11(3), 131-152.

Palincsar, A. S., & Brown, A. L. (1984). Reciprocal teaching of comprehension-fostering and comprehension monitoring activities. *Cognition and Instruction*, *1*, 117-175.

Philips, S. (1972). Participant structures and communicative competence. In C. Cazden (Ed.), *Functions of language in the classroom*, pp. 370-394. New York: Teachers College Press.

Polman, J. L. (1997). *Guiding science expeditions: The design of a learning environment for project-based science*. Unpublished doctoral dissertation, Northwestern University, Evanston, IL.

Polman, J. L., & Pea, R. D. (1997, April). Transformative communication in project science learning discourse. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago, IL, 1997.

Sarason, S. B. (1971). *The culture of the school and the problem of change*. Boston: Allyn and Bacon.

Scardamalia, M., & Bereiter, C. (1991). Higher levels of agency for children in knowledge building: A challenge for the Design of new knowledge media. *The Journal of the Learning Sciences*, *1*(1), 37-68.

Schön, D. A. (1982). *The reflective practitioner: How professionals think in action*. New York: Basic Books.

Wasley, P. A. (1994). *Stirring the chalkdust: Tales of teachers changing classroom practice*. New York: Teachers College Press.

Vygotsky, L. S. (1978). *Mind in Society*. Cambridge, MA: Harvard University.

Wertsch, J. V. (1981). Introduction: The problem of activity in Soviet psychology. In J. V. Wertsch (Ed.), *The problem of activity in Soviet psychology*. Armonk, NY: M. E. Sharpe.

Wertsch, J. V. (1991). *Voices of the mind: A sociocultural approach to mediated action*. Cambridge, MA: Harvard University Press.

Wertsch, J. V. (1997). *Mind as action*. New York: Oxford University Press.

Wittgenstein, L. (1967). *Philosophical investigations*. Oxford: Blackwell.