# Teaching by Design:
## Curriculum design as a lens on instructional practice

**Paper presented at the annual meeting of**
**the American Educational Research Association**
**April 11, 2001**

**Matthew Brown & Daniel C. Edelson**
**Northwestern University**

matt-brown@northwestern.edu
d-edelson@northwestern.edu

Introduction: The interaction between curricular materials and teacher practice

### 1.1 The lure of curriculum reform (the history)

Reformers have long been drawn to curricular materials as a mechanism for influencing the practices of teachers, though with limited success (Cuban 1992; Cuban 1993). One of the primary lures of curriculum materials is because, of all the different instruments for conveying educational policies, they exert perhaps the most direct influence on the tasks teachers actually do with their students each day. One of the most often cited reasons for the failure of curricular reforms is the resiliency of existing practices to change, and the likelihood that practitioners will "mutate" the core aims of the reform to take on the very characteristics the reforms seek to change (Cohen 1988; Brown and Campione 1996). Explanations for the continual disappointments of curriculum based reforms abound, focusing on the resiliency of teacher beliefs (Cohen 1990; Spillane 1999), conflicts between governmental policies and the realities of local instruction (Spillane 1998) and the inadequacies of professional development and teacher support (Wilson and Berne 1999; Putnam and Borko 2000). Implicit in many of these studies is the view that a fundamental gap exists between innovative curricular designs and existing teacher practices. The goal of the research program discussed in this paper is to unpack the mysteries of the teacher-tool interaction, focusing on the dynamic ways in which curricular designs interact with teachers' personal and contextual resources in the production of instructional practice. In particular, this paper will discuss a particular methodology for engaging in this kind of research—one in which the collaborative design of curricular materials can provide new insights into both the dynamics of instructional practice and the context of teaching.

In recent years, researchers have begun to examine deeply the ways that teachers plan, use, adapt, and learn from curriculum materials. Much of this work has stemmed from a key question posed by Ball and Cohen (Ball and Cohen 1996): "What is — or might be — the role of curriculum materials in teacher learning and instructional reform?" Since then, a number of studies have investigated how teachers plan, adapt, and teach with instructional materials (e.g. (Remillard 2000; Sherin and Drake under review)). Few of these studies, however, have adequately examined the specific design strategies for

producing "educative" curriculum materials, or the ways in which features in curriculum designs influence instructional practice.

This study adds to the current body of research exploring how teachers adapt curriculum materials, but takes a different path to understanding this interaction by viewing teacher appropriation of instructional resources as a design practice. I argue that the process of instruction involves teachers' mediation of cognitive and material resources—that is, what teachers do is create opportunities for learning through the mobilization and coordination of resources in order to accomplish their instructional goals. This interaction can be constituted as a partnership between teachers and tools. To understand this interaction, we must examine the ways in which particular designs constrain and afford different types of instructional practice, and the ways in which different local resources (both personal and contextual) empower or limit a teacher's ability to interpret, mobilize, and adapt these resources.

I argue that curriculum design can provide a powerful lens not only for understanding how teachers use & adapt curricular materials, but in that instruction is a process of mediation, a design perspective can shed light on the fundamental nature of instructional practice in general. The problem, however, is that we currently lack adequate tools for understanding how teachers interact with curriculum materials. What we need is a method that will help us gain simultaneous insight into the ways that ideas and practices are represented in curriculum designs, the nature of the resources that teachers bring to their practice, and the types of productive interactions that take place between personal, contextual, and cognitive resources during instruction. In short, what we need is a method for finding meaningful patterns in the myriad ways in which teachers use curriculum materials to achieved their goals.

### 1.2 At the nexus of design and practice (the problem & the solution)

To illustrate this perspective, consider the metaphor of teachers as bandleaders. Modern music has come to rely on sheet music as a representational medium for conveying musical ideas (i.e., Goodman 1976). Bandleaders, in turn, can interpret such musical

notations in order to reproduce the intended song. However, we know that no two renditions of a song are exactly the same. To take an example from the jazz world, if we compare a Duke Ellington rendition of "Take the A Train" to an Ella Fitzgerald version of the same song, we might make several observations: First, we have little difficulty identifying each rendition as being the same song. Second, we find that despite their core similarities the songs sound distinctly different (note that the same can often be said for two renditions by the same artist). Third, we can examine, as music critics often do, the sources of this variation—ranging from obvious differences such as instruments used to less obvious ones such as cultural influences, contextual factors, and stylistic preferences. And few would argue that, although the artists are using a pre-designed score as a foundation to support their practice, indeed a bulk of the creative work is taking place during the performance. Thus, a careful examination of the score (designed artifact) as well as the individual, contextual, and cultural capacities of each bandleader, we might learn a lot about the ways in which they interact to produce idiosyncratic yet meaningfully consistent performances—in other words, how performances can vary meaningfully while retaining a certain degree of allegiance to the designer's intent.

Those of us who study the design and use of curriculum materials can benefit from this comparison in considering our core design challenge—namely, how can we as designers of curricular innovations produce materials that are sufficiently flexible to be used in a diverse range of classroom contexts yet sufficiently resilient to retain the core principles of the reform? While the music and education communities differ greatly in terms of shared beliefs about practices and outcomes, we note that both communities rely on static artifacts to document and convey intended practices, and that teaching, like leading a band, is a dynamic process involving a combination of planning and improvisation. Furthermore, while both communities rely on prior practice and training, they also emphasize the important role of the actual performance in developing creative ability.

Historically, this tension between fidelity and variation in curriculum design and implementation has manifested along two opposing themes (admittedly over-generalized

here for the sake of illustration): centralized efforts to influence local practices through mechanisms of "remote control" (Dow 1991; Tyack and Cuban 1995; Cohen 2000) and localized initiatives to engage practitioners in the development of local solutions (McLaughlin 1976; McLaughlin 1990). While the former extreme promises stronger connections to the communities advancing the reform—and thus to the core principles of the intended innovation—the latter extreme promises stronger links to the capacities and sensibilities of those for whom the reform is intended, and thus to their local practices. We can also note the limitations of fidelity models: consider the blandness of a performer who plays a spiritless rendition of a song verbatim from the sheet music, and a similar case of scripted instruction. Similarly, we note that it is unrealistic to expect every bandleader to compose their own scores (though masters such as Ellington—and indeed many expert teachers—do this often).

Also separating the two fidelity and variation perspectives on implementation are the often conflicting values of the communities involved. This tends to be less of a factor in the music world, where one might note stronger ties between communities of composers and bandleaders than exist between curriculum designers and teachers. In the history of science reforms, for example, the domain experts, education researchers, and materials designers who produce reform-based curricular materials have frequently been motivated by different values and priorities than the teachers who used these reforms.

Yet reconciling the tension between fidelity and variation need not be seen as a choice between conflicting values or priorities. Rather, it is a matter of acknowledging two coexisting forces in the production of instructional practices—the fact that new ideas are introduced to classrooms via externally-generated policies and the fact that such infusions will be shaped and molded by the realities of local context during implementation. Instead of considering curriculum design and local implementation in opposition to each other, it is possible that the methods and practices of each perspective can inform each other. Such a possibility is even more evident when we recognize that what teachers do in their classrooms is interpret, mobilize, and apply available resources in order to achieve instructional goals. If we view this process as a partnership between actors and

tools (Pea 1993) then we recognize that in interpreting and adapting curriculum designs during instruction teachers are in many ways collaborating with the designers of those tools (Schön 1983). Understanding what teachers do from a collaborative design perspective can provide a powerful new perspective in understanding the nature and context of instructional practice.

### 1.3 The Global Warming Project

This study took place in the context of the Center for Learning Technologies in Urban Schools (LeTUS), a systemic partnership between researchers at Northwestern University and teachers in the Chicago Public Schools to design and implement inquiry-based curricular innovations for middle school science classrooms.[i] The curricular initiative discussed here is an 8-10 week science project examining the global warming controversy. In the Global Warming Project (GWP), students explore the causes and potential implications of the global warming controversy through investigations of scientific data. The project involves a scenario and role play: students act as advisors to the heads of state of various nations and must educate them about the key scientific factors involved, the challenges in knowing how these factors could influence changes in climate in different parts of the world, and possible ways to address these risks. In accomplishing these tasks, students explore content related to physical science (energy), earth science (climate), and the interactions between science, technology, and society. The GWP is build around a project-based pedagogy (Blumenfeld, Soloway et al. 1991; Gomez, Gordin et al. 1997) and utilizes technologies to support data visualization and analysis (WorldWatcher, Edelson, Gordin et al. 1999) and systems modeling (Model-it, Jackson, Stratford et al. 1994).

## 2 How is instruction collaborative design? (Theoretical background)

### 2.1 Venues for Collaborative Design

In this study, I focus on the ways that teachers and curriculum developers collaborate asynchronously through the use of materials during classroom instruction. However, there are several different ways of considering collaborative design in the Global

Warming Project. It will be helpful to distinguish briefly three venues for collaborative design, occurring prior to, during, and after implementation of the project.

The initial design of the GWP came out of a joint collaboration between teachers, researchers, and technologists, dubbed a "Work Circle." This collaboration sought to integrate prior experiences of researchers in developing tools and activities to support inquiry-based climate studies and prior experiences of teachers in working with their students. Through ongoing conversations, brainstorms, and design tasks, the group produced materials which were both informed by current innovations in science education research and at the same time appropriate to and useful for urban middle school science classrooms. While researchers sought to introduce key ideas and values from recent science reforms (e.g., ways of introducing authentic scientific practices within classrooms; constructivist and inquiry-based approaches learning), teachers tended to represent the realities of local contexts, including student capabilities, time limitations, and subject-matter mandates dictated by standardized testing. This work has been discussed in greater detail elsewhere (e.g., Brown and Edelson 1999; Shrader, Williams et al. 1999).

During the implementation stage of the GWP, researchers gathered several case studies in order to trace patterns and variation in each teacher's enactment of the GWP. This work, which aims to unpack the dynamics of the teacher-tool partnership, forms the basis of the current study and will be detailed shortly.

Following each enactment cycle, teachers and researchers met again to share insights, observations and new ideas. This feedback, combined with lessons taken from classroom observations and studies of student work, were applied to several iterative redesigns of the GWP. Refinements sought to provide better ways of supporting teacher practices, such as the development of "activity pairings" which coupled technology tasks with conventional classroom labs. They also sought to address conceptual challenges for students, such as more explicit strategies for understanding the relationships between climate factors. Finally, efforts were made to re-evaluate the core scientific frameworks,

representations, and practices on which the work was based. For example, this refinement stage led to new ways of representing the climate change issue as one of large-scale systems in and out of balance.

Each of these stages represents a way of understanding how the communities of research, development, and scientific practice can collaborate with teacher communities in order to produce inquiry-based instruction. Furthermore, each provides a means for negotiating the tension between ideas, beliefs and goals of communities external to classrooms—such as concepts and practices of the scientific community, and insights into learning and pedagogy generated by the educational research community—and ideas, beliefs, and goals internal to classrooms—such as those of teachers and students.

In each case, furthermore, the central focus of design is curriculum materials. In work circles, researchers and teachers negotiate languages, beliefs, goals, and practices in a synchronous collaborative setting. The refinement stage involved a combination of synchronous collaboration (sharing of feedback) and asynchronous collaboration (applying lessons from classroom observations and re-evaluating outcomes design in terms of alternate domain representations). Other research has addressed the nature of collaborative design in work circles (Brown and Edelson 1999; Shrader, Williams et al. 1999) and the ways in which lessons from implementations can be applied to redesigns (Brown and Edelson 1999; Sherin, Edelson and Brown 2000; Edelson in press). In this study, however, I am particularly concerned with the asynchronous collaboration, across time, between actors contributing to the GWP design. Thus, this paper aims to explore the dynamic interactions that occur, via curriculum materials and during daily classroom instruction, between researchers, developers, scientists and teachers. To do this, it is first necessary to explain how instructional practice can be viewed as design work.

### 2.2 The design of teaching (Ways of thinking about the issue)

To understand how instructional practice can be conceived of as a design process of design, consider what teachers do each day in their classrooms. Few would argue that teaching can be a creative process, and this can mean much more than simply writing

lesson plans the night before class. Even during class, teachers actively shape the instructional environment using available resources in order to achieve their goals. Instruction is not a solitary activity, but rather a partnership between teachers and tools (Wertsch 1991; Pea 1993). In recognizing that instructional capacity is not solitary, we also recognize the crucial roles that teachers (as actors) play in mediating these resources in ways that help them to achieve desired outcomes (Wertsch 1991). If we expand our description of tools in the environment to include not just physical objects but also language, cultural schema, belief systems, divisions of labor, and rules (Wartofsky 1973; Cole 1996) we might consider that classrooms are, in many ways, distributed systems of activity (Cole and Engstrom 1993). In that the mediation of resources (physical, cultural, conceptual) during instruction yields settings in which learning can take place, I view the process as a genre of design.

In considering the ways that teachers work with instructional tools while teaching, it is useful to note the factors which influence how such tools are used. Following a notion advanced by Gibson (Gibson 1977) and later by Norman (Norman 1988) we acknowledge the role of a tool's *affordances* and *constraints* in influencing how that tool is interpreted, adapted, and put to use. The features of a tool's design have a communicative potential—one that we might readily acknowledge in musical scores and curriculum materials. This *transformative* view of curriculum design stands in marked contrast to the *transmission* advanced by advocates of "scripted" or "teacher-proof" curriculum (Pea 1993; Remillard 2000). Thus, when a teacher interprets the affordances of a pre-rendered curricular design he or she is in a sense *collaborating* with that tool's designer (Schön 1983). In that teaching with curriculum materials involves a collaboration the materials' designer in order to produce new settings to support classroom learning, I view teaching—or the process of instructional mediation—as a form of collaborative design.

At the root of this perspective is an expanded notion, alluded to above, of what designed artifacts are. Following Wartofsky and Cole (Wartofsky 1973; Cole and Engstrom 1993), I distinguish between primary, secondary, and tertiary artifacts. *Primary* artifacts are

akin to the physical objects we most often speak of as "tools" and in the case of curricular materials constitute tools for measurement, analysis and observation (e.g., in the GWP these include rulers, WorldWatcher, globes). While primary artifacts constitute objects which contribute directly to goal-driven action, *secondary* artifacts constitute representations that contribute to the transmission of skills necessary to carry out such production. Thus, they include tasks, cultural scripts, and symbol systems—or in the case of science, mechanisms for transmitting the systems of practices and beliefs which dictate scientifically meaningful use of lab tools. Secondary artifacts manifest in the GWP materials through visual representations (diagrams, graphs, models), task structures, and scripted procedures. In that each of these exists in a physical as well as conceptual format, we notice that secondary artifacts have both material and ideal dimensions. *Tertiary* artifacts constitute an imaginary, expressive world, in which outcomes are characterized less by their contribution to the fulfillment of immediate goals than by their relation to an autonomous world of "free play" (Wartofsky 1973). In the GWP, these include imaginary scenarios (representing heads of state regarding a global controversy), roles (scientific advisors), and narrative storylines (the "macro" task structure that links sequences of scientific investigations throughout the project).

The challenge of representing rich, dynamic scientific practices in curriculum materials lies in negotiating the three levels of artifacts in the production of what ultimately exists as a static stack of paper. A musical score exists simultaneously as a material object, a conceptual representation, and imagination-stimulating work of art. Furthermore, it's potential is directly linked to the individual who is using it—to someone who cannot read sheet music it is a piece of scrap paper; to one who can read the music it conveys a rich array of tones and rhythms; to an expert musician or bandleader it stimulates the imagination to new heights of interpretation and expression. Understanding the makeup of curriculum materials, in that it exposes the different levels in which artifacts can communicate cultural practices, is a useful and important means for learning more about the resources which practitioners bring to the collaboration.

# 3 Methods

## 3.1 Research Framework

To understand the interaction between curriculum materials and teacher practices, it is necessary to examine instructional practice both from both sides of the teacher-tool partnership. The framework for analysis focuses on how resources contributed by both curriculum materials and teachers interact in order to produce instructional outcomes (fig. 1). Using tasks as a unit of analysis, I examine the similarities and variations in the ways that teachers use resources during instruction in order to achieve their goals. In this sense, teacher tasks constitute the products of instructional mediation. For instance curriculum resources might contribute differentially to the ways that teachers facilitate investigations, lead discussions, evaluate student progress, explain & frame concepts, model practices, or manage interactions. To unpack the ways in which curricular resources and teacher resources interact I first examine the resources which the materials contribute to instruction as well as the strategies used for representing them. This stage of the analysis relies primarily on the notion of artifacts discussed above. I also examine the personal and professional resources contributed to instruction, focusing primarily on knowledge resources, but also including contextual elements such as material, cultural, and human resources (i.e., students) which contribute to classroom activity.

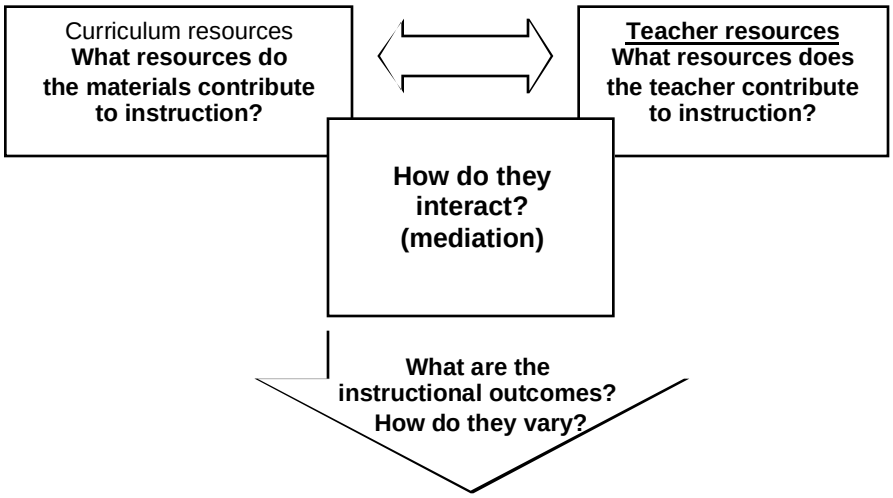


**Figure 1: Research Framework**

By examining the resources contributing to teacher practice, I aim to unpack the dynamics by which teachers mediate personal, curricular, and contextual resources in support of instructional tasks. In order to understand the different ways in which this dynamic unfolds, I adopt a Vygotskian framework for scaffolded practice (Vygotsky 1978), whereby teachers rely on artifacts according to their developmental expertise. In some cases, teachers rely completely on curricular resources in order to carry out instructional tasks. In these situations, the teacher "offloads" the design burden on the curriculum materials, such as verbatim adherence to a scripted procedure. In other cases, the teacher "adapts" the materials in light of perceived affordances and opportunities in order to meet instructional goals. Such situations represent a shared design burden between the teacher and the curriculum materials. In still other cases, the curriculum materials provide the teacher with inspiration, but the resulting practice is largely the teacher's own personal creation. This I term "instructional improvisation."

### 3.2 Data Analysis

The research discussed here is based on comparative case studies of three teachers' experiences with the GWP. Two of the teachers had prior experience enacting project-based science curricula; the third was a relative newcomer to this approach. However, each teacher was using the GWP materials for the first time. Data collected included

classroom video (mainly following the teacher), teacher interviews based on classroom experiences, and email correspondence, supplemented by some student interviews, student work, and a record of design modifications made to the GWP.

Iterative coding of instructional practice focused on teacher tasks (e.g., facilitating investigations, modeling practices), curricular resources (e.g., types of artifacts involved), classroom resources (e.g., available resources, established norms), and teacher knowledge (e.g., goals, beliefs, content understanding, pedagogical content knowledge). In each task sequence, analysis focused on identifying the nature of the interaction (e.g. offload, adaptation, improvisation), types of representational strategies in the curricular resources, cross-classroom comparisons of resources and outcomes, and evidence of triangulation.

# 4 Cases

## 4.1 Three Teachers, Three Schools

Janet is a longtime veteran of project-based instruction. Originally trained as a social studies teacher, she accepted a position as a science teacher 15 years ago "because no one else wanted the job." A self-described maverick, she views her student-centered, open-ended teaching style in contrast to the "teach to the test" mentality that has pervaded each of the four Chicago Public Schools where she has worked. She teaches at a relatively high achieving school in a predominantly middle class neighborhood. The school has relatively low student mobility, and 32% or the students are considered low income. The student population is 61% white, 4% black, 18% Asian, 17% Hispanic.

Bill is a 29-year veteran of the Chicago Public Schools, having spent 12 of them at his current school. He has a reputation among his peers as being a highly motivated teacher, and has been involved in several high-profile School Board initiatives. Bill runs his classroom in an efficient and orderly fashion, and though his students engage in a wide range of "hands on" activities, he is generally at the center of the action. He has a strong background in science and technology and his classroom is a veritable "treasure trove" of science gadgets and binders containing curriculum resources from his various past

endeavors. His school is a racially and ethnically diverse magnet in a predominantly upper middle class neighborhood. The student population is 25% white, 43% black, 12% Asian, 19% Hispanic. 52% qualify as low income.

Brenda has been in the classroom for 7 years, having left an earlier career as a dietician to become a teacher. She has a strong science background, though tends to adopt a more traditional, didactic pedagogy. She teaches in a lower-achieving school, where 20% of the students have limited English skills and 82% are low income. The student population is 20% white, 2% black, 54% Asian, 24% Hispanic, with a high percentage of first-generation immigrants.

### 4.2 Activity: Investigating the Sun's Rays

While the analysis covered the entire GWP, the current discussion is based on a particular activity, which came roughly midway through the GWP. In this activity, students investigate how and why temperatures on Earth vary by latitude focusing in particular on the angle at which the sun's rays strike the surface. Using flashlights to simulate sunlight, students shine the light at various angles onto a sheet of graph paper, tracing the perimeter of the light circles at each angle. By counting the squares for each circle, students calculate the area. For example, when the light is perpendicular (90°), the area winds up being smaller than when the light shines at a more extreme angle (i.e., 40°). By calculating the ratios between the areas of light for each angle, students can, on the assumption that the light source has remained consistent, extrapolate that as angle decreases and area increases, light intensity decreases.

A crucial element of this activity is understanding the connections between the lab model and the Earth-sun relationship. The flashlight represents the sun's rays and the graph paper represents Earth's surface. Shining the light perpendicular to the graph paper (90°) approximates the relatively direct manner in which sunlight strikes the equatorial regions. By contrast, shining the light at an extreme angle to the graph paper simulates the indirect manner in which sunlight strikes the polar regions.

This activity is situated at the beginning of a larger sequence of activities which explore the question "What makes earth warm?" The sequence is structurally organized into activities exploring the "sun, Earth's surface, and the atmosphere," with both WorldWatcher activities and traditional physical labs investigating each factor. The lesson plan for this activity provides lists of suggested materials, vocabulary, a step-by-step procedure for setting up the investigation, key questions, instructions for doing the intensity calculations, and a range of teacher tips pertaining to both subject matter and procedural issues. For a number of reasons—ranging from expedience, to pilot-testing observations, to preferences of the work circle team members—the Sun's Rays activity is rendered in the GWP materials to emphasize data collection using a suggested model for representing the Earth-sun relationship.

### 4.3 Janet: An example of an instructional adaptation

Janet made several key adaptations when doing the Sun's Rays activity with her students. Rather than have her students follow the "recipe" for doing the lab, she decided to turn the activity into an opportunity for them to engage in experimental design. Instead of providing them with a set list of materials, she gave them access to a host of supplies which she gathered from her own supply closet and borrowed from other teachers. And rather than just connect the elements of the lab model to the actual phenomena they represented, she relied on the model throughout the lesson as a means to stimulate deep reflection and analysis of the results..

After introducing the days task—to determine how the angle of sunlight influences temperature differences on Earth—and discussing with students some possible ways of constructing a model to illustrate this phenomenon, Janet divides the class into small groups to devise ways of setting up the experiment. As they work in groups, she interjects periodically in order to foster sharing amongst the groups and focus their attention on key issues or questions. At one point she raises a key problem several groups are having: how can they support the lights so that they can be held in place at different angles? As they discuss this engineering challenge, she reminds the class of their goal—to measure light at different angles—and questions them on what the

materials are representing. After some discussion, she asks them if their current setups are sufficient for their goals.

Janet's adaptations of the curricular resources reveal several things about her instructional capacity and provide an interesting lens for interpreting her personal and contextual resources. It begins with her ability to perceive in the Sun's Rays activity an opportunity for fostering open-ended experimental design. Note that she does not adapt every lab in this way; there is something about this particular task that stimulates this practice. Given the extent to which she continually focuses students' attention on the nature of the lab model—in particular, the mappings between lab components and the phenomena they represent—it is likely that the rich "analogy" provides a key affordance for her adaptation. Contrary to several other labs in the GWP, the analogy here is not immediately apparent, and therefore lends itself well to deeper discussion and analysis (note that the does not encourage experimental design in the following lab, in which students measure temperature increases of several different colored envelopes placed under a lamp).

But there is a further source of explanation for this adaptation, revealed in the following comments, made a few days after the class described above:

> When I do labs now, I try to be very careful to not be so prescriptive that I eliminate the opportunity for the kids to use creative thought in setting up a lab. So, the first day, I did not give them the lab sheet. I just said we were going to check out this angle question and here was what we were going to use. I provided the peg boards, the flashlights, and a bag of materials from the Math teacher... I let them have the rest of that period to devise a set up.
>
> (Email Correspondence, 2/5/200)

These comments reveal Janet's goal of providing opportunities for creative thought and her belief that ideas should originate from the students, not her. She mentions a decision not to use student worksheets provided in the GWP in order to foster a more open-ended atmosphere. Embracing this approach requires a certain level of comfort with the scientific practice of experimental design, which Janet clearly possesses. In fact, other examples from Janet's classroom reveal that this a strategy that she commonly uses, and

thus we could expect that she possesses a certain procedural script for accomplishing it. She also incorporates physical tools not originally called for, such as pegboards (which she made while at an earlier school) and additional resources she managed to borrow from the Math teacher. Each of these elements represents a resource contributed by the teacher or her context to the instructional partnership which helps to support her adaptations.

### 4.4 Janet: An example of an instructional offload

Adapting the Sun's Rays lab requires a certain level of comfort and expertise. Yet when such a comfort level is not present, as was the case during a later stage of data analysis, the outcomes look very different.

After the students finished collecting their data, they began interpreting their results. In addition to their visual observations that the larger circles of light seemed "less bright," they sought a way to support these observations numerically. The lesson plan provided instructions on calculating the ratios of each area to the "base" value of 90°, but Janet was clearly uncomfortable with the procedures. In the days before she tried it in her classroom, she commented that the intensity calculation was "driving me nuts."

> I wanted to do it only because of the idea of being able graphically to show something…. Each day I think I will try it today and then… I mean it took me two days of doing it to figure out why I am doing it. (Interview 2/8/00)

This discomfort manifested in Janet's almost verbatim reliance on the lesson plan during class. The lesson unfolded with Janet standing in front of an overhead projector, lesson plan in hand, leading students step-by-step through the intensity calculations. The first step, which is to determine the increase in area between 90° and 80° takes her nearly 5 minutes to get through. Given the other evidence of student performance, it is likely that the time spent here was less due to the difficulty of the subtraction operation than it was due to the teacher's lack of task monitoring. In other words, she was focusing more on the "trees" than the "forest," a common result of following scripts verbatim. She concludes the first step by asking if everyone gets it. "Easy, right? It gets worse!"

As the task proceeds, her discomfort grows, and she leans more and more not only on the lesson plan, but on students who suggest alternate ways of doing the calculation. Janet's range of instruction here is limited. She has difficulty diagnosing errors and is unable to respond constructively to student questions. "Perhaps my confusion caused it to be more difficult," she admits, "but it wasn't pretty" (Email Correspondence, 2/10/200).

However, not all offloads were so unproductive. On other occasions, structured student worksheets helped Janet to use WorldWatcher in ways that she would otherwise not have been able to produce on her own. Occasions such as these helped to increase her comfort level with the software tool, for she could rely on student worksheets to structure student work while herself focusing on coaching students through comparisons of visualizations. Furthermore, in watching students go through the steps of the task, she had the opportunity to learn about features and capabilities of the tool that had previously been invisible to her. The worksheets helped to bring about productive opportunities; they reflected the experience and expertise of their designers. In a sense, then, the designers were present in the classroom, their artifacts helping to create learning opportunities that would not have been possible otherwise. Relying on this basic level of support, Janet was then able to explore new areas of her practice—namely the geospatial representation of phenomena which they had previously only been capable of representing through lab simulations.

### 4.5 Bill: An example of instructional improvisation

Bill provides an example of how the basic features and constraints of an activity can provide inspiration for instructional improvisation. In this last type of resource use, the bulk of the design burden lies with the teacher. In that the results stem more from the teacher's own expertise than from the designs in the GWP, instructional improvisation is the most difficult of the three types to account for. However, it is possible to note likely areas of connection between teacher and curricular resources.

In the class before the start of the Sun's Rays lab, Bill decides to stimulate a class discussion to provide a conceptual link between the new task and their earlier investigation of temperature variation. Out of nowhere, he asks the class, "How would you know what to pack for a trip to Disney World?" After some discussion, a student points out that they know Orlando will be warm because it is in Florida, and Florida is usually warm due to it's proximity to the equator. Satisfied, Bill then asks his students to consider why he would ask such a question.

| | |
|---|---|
| Bill: | Why do you think I would ask this question right now? |
| Charles: | Because you're going to Disney World? |
| Bill: | Why would I ask how you would decide to pack clothes? |
| Shamika: | So you would know how to predict weather in different areas without using the weather [report]. |
| Joshua: | So we know how temperature is over different locations. |
| Bill: | Hands down, enough said. Joshua, could you repeat that? |
| Joshua: | So we know how temperature changes over different locations. |
| Bill: | That's one part of it. If instead of Disney, what if I'd have said the Alps in Switzerland, then you would have said something different about types of clothes… |
| Bill: | Tomorrow, we're going to investigate that question-- why does temp change according to latitude. |

Bill frequently creates spontaneous analogies such as this one in order to stimulate students' thinking about scientific topics, a strategy that he calls "attention grabbers." In a similar situation, Bill asked the students to consider the role of colored in reflecting and absorbing solar energy by asking them what would happen if he painted Las Vegas, which is surrounded by a light-colored dessert, black. The ability to create such analogies points to a deep structural understanding of the domain, an is a sign of expert understanding (Gentner 1983). But in evaluating such creations, it is equally important to recognize the object of the analogy. What is the source of the base concept in the classroom? Certainly Bill's own scientific understanding is a key source. Yet we also recognize the role of the curriculum design in situating the concepts and framing key questions. For example, the Sun's Rays lab was deliberately placed after investigations on how temperature varies by latitude. This helps to beg the question Bill is asking in the first place. Furthermore, the sequence begins with the angle of incoming solar energy

rather than other sources of temperature variation, such as the reflectivity of surfaces. In other words, the sequence of activities and the ways in which they relate to each other exerts a strong influence on how practitioners interpret them, even when the bulk of classroom design seems to be originating from the teacher.

### 4.6 Comparison

The goal of this paper is to illustrate the ways in which a framework for analyzing design collaborations between teachers and curriculum materials can yield insights into different types of instructional practice. They examples I have provided illustrate three types of teacher-tool interaction. The next step is to use the framework to trace patterns of similarity and variation in each teacher's implementation of the GWP. There is insufficient space to do so here. However, figure 2 provides a brief illustration of some different instructional tasks in the GWP and how each teacher adapts, offloads, or improvises in the process of producing that task.

| *Task* | **Janet** | **Bill** | **Brenda** |
|---|---|---|---|
| **Provide Background** | Has groups of students design their own models of the climate system (adaptation) | Creates analogous scenario: Knowing how to pack for Disney World (improvisation) | Leads students through a step-by-step recording of vocabulary terms; fill in a blank diagram of the EB (offload)<br><br>Brings in her own Energy Balance diagram (adaptation) |
| **Introduce task** | Introduces task with a discussion of three sub-sections of the unit. (improvisation) | Introduces task with an analogy between light intensity & paint distribution. (improvisation) | Introduces task by reminding them of similar activity from last year. |
| **Set-up Investigation** | Students design their own setups using available materials -- some extras. (adaptation)<br><br>Asks students to evaluate sufficiency of their models (part of same adaptation) | Demonstrates light sensor (adaptation)<br><br>Passes out re-written worksheets (adaptation)<br><br>Provides new materials (adaptation) | Introduces **lab model mappings**. Tells students the purpose. Demonstrates how the flashlights are used. Gives detailed instructions. (offload)<br><br>Simplifies lab sheet (adaptation)<br><br>Uses verbatim tool setup (offload) |
| **Support procedure** | Coaches students in groups (adaptation)<br><br>Has them support each other (adaptation) | Has students read procedure. Does one step at a time with whole-class (offload) | Rethinks procedure as lab proceeds- ??reduces number of angles? (from offload--> to adaptation) |

**Figure 2: Comparison of teacher-tool partnershipsin the GWP**

# 5 Conclusions

## 5.1 Further Analysis:

The current study aims to illustrate a framework for using teacher-tool collaborations in order to learn about the context of instructional practice, whereby teachers' instructional practices can be explained in the context of daily design collaboration involving curriculum materials. This framework relies on different levels of mediation to expose the resources which are present during instruction and which help teachers mobilize curricular, personal, and contextual resources in order to achieve their goals.

Yet this is only the first step to understanding how teacher practices and curricular materials interact and how this design partnership can yield insights into instructional practice. However, further work is necessary in order to establish greater causal linkage between specific teacher resources and features in the curriculum—in other words, to explain *why* certain resources contribute to certain outcomes. One challenge in establishing causality is the difficulty of capturing teachers' decision-making processes. Many decisions to adapt materials, for example, are made prior to instruction and are subject to innumerable influences. Furthermore, teachers often have a hard time articulating their reasons for making such decisions. In some cases, however, it is possible to document decision-making processes as they are happening. Discourse analysis of such instances can provide rare glimpses into the factors which prompt certain decisions.

More work is necessary to explore such situations, particularly studies of teacher development over time and using larger samples of teachers. But the benefits of understanding these conditions is clear: knowing why and how different resources support different types of instruction can help designers better understand how teachers move through the different levels of mediation and better design features that support teachers in moving through these levels of practice.

Further work is also needed to explore the consequences of different instructional outcomes. For example, when does an instructional adaptation become a lethal mutation? When does an instructional offload constitute a mindless following of a script (i.e., a "lethal non-mutation")? One possible approach is to develop clearer criteria for determining when a teacher has adequately created opportunities for student learning. Such an approach could clearly identify occasions when teachers failed in this regard, through proving success is more of a challenge. Another approach might include assessments of student learning in response to each type of partnership. However, such results are likely to be colored my myriad other influences both in and out of the classroom to the extent that evaluating outcomes based on test scores presents problems.

At the very least, such work prompts us to ask important questions about how we value variations (as constructive or problematic), about the developmental implications of instructional mediation, and about the role of representational strategies in supporting human action. Further inquiries into how teachers use instructional resources promises to inform not only the ways that we design curricular materials to support practice, but also the ways we think about professional development and pre-service training.

Using the context of collaborative design perspective to study instructional practice is important not only because design tasks constitute a significant portion of what teachers do each day, but also because the design process provides a unique lens for understanding the relationship between capacity and action. The problem is that while most people can recognize when classroom variations are and are not effective, few can explain why this happens. With time, we may come closer to understanding what it is about two seemingly different classroom outcomes that allows us to claim equal levels of success.

# Bibliography

Ball, D. and D. K. Cohen (1996). "Reform by the book: What is — or might be — the role of curriculum materials in teacher learning and instructional reform?" Educational Researcher **25**(9): 6-8, 14.

Blumenfeld, P. C., E. Soloway, et al. (1991). "Motivating project-based learning: Sustaining the doing, supporting the learning." Educational Psychologist **26**: 369-398.

Brown, A. L. and J. C. Campione (1994). Guided discovery in a community of learners. Classroom lessons: Integrating cognitive theory and classroom practice. K. McGilly. Cambridge, MA, MIT Press**:** 229-270.

Cohen, D. (1990). "A Revolution in one classroom: The case of Mrs. Oublier." Educational Evaluation and Policy Analysis **12**: 327-345.

Cohen, D. K. (1988). Educational technology and school organization. Technology in education: Looking toward 2020. R. S. Nickerson and P. P. Zodhiates. Hillsdale, NJ, Erlbaum**:** 231-264.

Cole, M. (1996). Cultural Psychology. Cambridge, MA, Belknap Press, Harvard University Press.

Cole, M. and Y. Engstrom (1993). A cultural-historical approach to distributed cognition. Distributed Cognitions: Psychological and educational considerations. G. Salomon. Cambridge, Cambridge University Press.

Cuban, L. (1992). Curriculum Stability and Change. Handbook of Research on Curriculum: A project of the American Educational Research Association. P. W. Jackson, Macmillan Publishing Co.

Cuban, L. (1993). "The lure of curricular reform and its pitiful history." Phi Delta Kappan **75**(2): 182-185.

Dow, P. (1991). Schoolhouse politics. Cambridge, MA, Harvard University Press.

Jackson, S. L., S. J. Stratford, et al. (1994). "Making dynamic modeling accessible to precollege science students." Interactive Learning Environments **4**: 233-257.

Norman, D. A. (1988). The Design of Everyday Things. New York, Basic Books.

Pea, R. D. (1994). "Seeing What we Build Together: Distributed Multimedia Learning Environments for Transformative Communications." Journal of the Learning Sciences **3**(3): 285-299.

Schön, D. (1983). The Reflective Practitioner: How Professionals Think in Action. New York, Basic Books.

Spillane, J. (1999). "External reform initiatives and teachers' efforts to reconstruct their practice: The mediating role of teachers' zones of enactment." Journal of Curriculum Studies **31**: 143-175.

Spillane, J. P. (1998). "State policy and the non-monolithic nature of the local school district: Organizational and professional considerations." American Educational Research Journal **35**: 33-63.

Vygotsky, L. S. (1978). Mind in society: The development of the higher psychological processes. Cambridge, MA, Harvard University Press.

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

---

[i] The Center for Learning Technologies in Urban Schools, known as LeTUS, is a collaboration between Northwestern University, Chicago Public Schools, University of Michigan, and Detroit Public Schools, and is sponsored by the National Science Foundation under grant # REC-9720383. The research described here has also been supported by the NSF under the WorldWatcher Curriculum grant, # ESI-9720687.