letus

Design Brief

Teaching As Design:

Can we better understand the ways in which teachers use materials so we can better design materials to support their changes in practice?

Matthew Brown, University of Illinois at Chicago
Daniel C. Edelson, Northwestern University

The Center for Learning Technologies in Urban Schools, a partnership among:
Chicago Public Schools
Detroit Public Schools
Northwestern University
University of Michigan

Funded by the National Science Foundation

The Center for Learning Technologies in Urban Schools

The National Science Foundation-funded Center for Learning Technologies in Urban Schools (LeTUS) strives to improve science education in urban areas by changing the face of science teaching and learning. LeTUS is a partnership among university and public school educators and researchers from the Chicago Public Schools, the Detroit Public Schools, Northwestern University and the University of Michigan. They collaborate on the design and implementation of science curricula and focus on:

- Collaborating with urban schools
- Designing project-based science curricula
- Developing interactive computing technologies
- Bringing about systemic education reform
- Working to improve the intellectual lives of all children

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Abstract

The interpretation of teaching as design is a relatively new area. This paper explores how teachers interact with materials and, by doing so, alter the unit's design elements.

It explores one teacher's enactment of a particular unit in the Global Warming curriculum developed by the Center for Learning Technologies in Urban Schools, a partnership among the Chicago Public Schools, the Detroit Public Schools, Northwestern University and the University of Michigan. This paper also examines instances of the teacher using available resources to adapt, offload and improvise within the unit.

Through this examination, the authors establish the Design Capacity for Enactment framework and contemplate the benefits and successes of teachers' pedagogical design capacity as it pertains to the art of teaching as design.

School reformers frequently have relied on curriculum materials as a mechanism for influencing teachers' practices, though with limited success (Cohen 1988; Cuban 1992; Cuban 1993; Ball and Cohen 1996). A primary lure of curriculum materials is that, of all the different instruments for conveying educational policies, they exert perhaps the most direct influence on the tasks that teachers actually do with their students each day in the classroom.

Explanations for the continual disappointments of curriculum-based reforms abound, including the resistance of teachers to change their beliefs (Cohen 1990; Spillane 1999); conflicts between government 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). These examples illustrate the resistance of existing classroom 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.

There is good reason to be skeptical about the influence curriculum materials can have over teacher practice. The use of curriculum materials provides no guarantees of instructional transformation. If, however, we appreciate that teaching is a process of design and we view materials as resources to support such a process, then the errand of such materials shifts from transmitting instruction to transforming it by serving as a catalyst for local customization. More than mere conduits for reforms, materials that support teacher-design stand a better chance of engaging practitioners with the curricular ideas the reforms intend to foster.

Interpreting Teaching As Design

Teacher practice is, in many ways, a design activity. Teachers must perceive and interpret existing resources, evaluate the constraints of the classroom setting, balance tradeoffs and devise strategies – all in the pursuit of their instructional goals. These are all characteristics of design.

The interpretation of teaching as design is relatively new. The notion of teachers as designers is compatible with a range of cognitive research that emphasizes the role of artifacts in determining human activity (Norman 1988; Norman 1991; Wertsch 1991; Pea 1993; Cole 1996; Wertsch 1998). This research highlights three key points in the notion of teaching as design: (a) curriculum materials play an important role in affording and constraining teachers' actions; (b) teachers notice and use such artifacts differently given their experience, intentions and abilities; and (c) teaching by design is not so much a conscious choice but an inevitable reality.

Recent efforts have sought to understand the complicated relationship between curriculum materials and instructional practice by examining the ways that teachers plan, use, adapt and learn from curriculum materials (e.g., Ben-Peretz 1990; Remillard 2000; Sherin and Drake 2003). Few studies, however, have focused on ways that features and design strategies in curriculum materials influence instructional practice.

This study attempts to understand the teacher-material encounter by exploring the ways that specific curricular designs influence practice, and the ways that different teachers interact with these designs in light of their unique knowledge, skills and commitments. In fact, teachers create, adapt and improvise with instructional resources most of the time. The goal of this study is to unpack the nature of these dynamics and explore the factors that shape them. These findings promise to inform the ways that materials designers create instructional resources.

Our basic premise is that, regardless of intent, teachers invariably notice and use different elements of curricular designs as they customize them to their idiosyncratic needs and contexts. For example, how teachers interpret and appropriate a given curricular feature is likely to be influenced not just by the nature of the curricular artifact, but also by their understanding of the relevant subject

matter, their familiarity with the recommended instructional strategies, their knowledge of student understanding and their beliefs about teaching and learning.

Given this premise, we aim to develop analytical tools for making sense of the patterns that emerge in teachers' use of materials, in order to understand better how to design materials that accommodate what we see as the design process inherent in everyday teaching. Our ultimate goal is to devise strategies for crafting resources that support teaching as design while offering sufficient guidance with respect to the core curricular content. To do this, we must find a middle ground between expecting teachers to adopt materials "as-is" and expecting them to develop materials from scratch.

Historical Perspective

Past curriculum reform efforts focused on the ways teachers implement curriculum, that is, whether what the teachers do in the classroom is close to the spirit or intention of the curriculum. Historically, there have been two approaches.

Some have sought to shape what students learn through "remote control" mechanisms that limit practitioner discretion over the curriculum (Welch 1979; Dow 1991). Others have sought to engage practitioners in "mutual adaptation" of reforms by encouraging them to find local pathways to a common vision (McLaughlin 1976; Elmore 1979; McLaughlin 1990). While the former approach emphasizes fidelity to the recommended reforms, the latter encourages local variation (Snyder, Bolin et al. 1992). Both approaches, however, seek the fundamental goal of achieving outcomes that align with the core vision of the reform.

Both the fidelity and variation approaches have their advantages and disadvantages. For example, remote control reforms afford efficient and widespread dissemination of ideas and retain strong links to the intended goals and to core principles. However, while the remote control method may be attractive to school boards under increasing accountability standards, critics note that reforms adopting a "one-size-fits-all" approach are bound to encounter classroom-level resistance since they overlook the unique qualities of individual teachers, the diverse needs of students and the high variability of classroom and school contexts. On the other hand, reforms that adopt the mutual adaptation method are more likely to yield locally relevant solutions and provide greater opportunity for transforming the attitudes and skills of local practitioners. However, critics have questioned the scalability of such efforts because they are labor intensive, require extensive practitioner commitment, are difficult to share across sites and risk dilution of the core principles that make them innovative in the first place. Furthermore, teachers often lack required materials development expertise.

From a materials development perspective, the tension can be seen as a dichotomy between materials that capture and communicate the goals and methods of the reform and locally situated, practitioner-driven design. This dichotomy underscores the need to understand the ways that materials render and convey reforms as well as the ways that teachers interpret, appropriate (or resist) and modify such resources within daily practice. The study discussed here provides a new way of thinking about the fidelity-variation tension by exploring teachers' use of curriculum materials from a design perspective.

Understanding the Intersection between Teacher Practice and the Design of Curricular Innovations

Examining teaching as design helps to illustrate the dynamics that influence the outcomes of teachers' use of curriculum materials. This study examines the intersection between teacher practice and the design of curricular innovations. It explores the ways that three urban middle school teachers interacted with the materials in a specific middle school unit, devoting particular attention to the nature of the curriculum designs and the ways that

teachers used these resources to design instruction. The research involved multiple cycles of observation and analysis of classroom practice based on qualitative investigation of classroom video, teacher interviews and the curricular artifacts themselves. This report focuses on the experience of one of the three teachers.

The Global Warming Project is a 10-week, inquiry-based classroom science project developed in collaboration with the Chicago Public Schools as part of the activities of the Center for Learning Technologies in Urban Schools (LeTUS), in which middle school students investigate the science of climate in the context of the controversial global warming debate.

As a materials-supported curricular reform, the Global Warming Project (GWP) embodies features of both the remote control and mutual adaptation approaches. On one hand, the GWP developed through a collaborative partnership between university researchers (including the author of this study) and middle school teachers that aimed to bridge the gap between research and practice. Thus, it exhibits many characteristics of the mutual adaptation approach. On the other hand, the curriculum materials that resulted from this development effort provided an instrument for spreading the innovation to teachers who were not part of the initial development effort and thus provided a mechanism for influencing classroom practice remotely. In these two ways, the GWP involves elements of both the mutual adaptation and remote control perspectives: While the ideas and practices in the GWP were crafted based on the needs and realities of local practitioners, the finished product embodied a set of core ideas and goals that the developers were interested in preserving at scale.

Characteristics of and Variations in Practice

The first stage of analysis involved a single teacher's implementation of one activity, the Sun's Rays Lab. The analysis illustrates three basic patterns of use. First, while the materials provided a detailed recipe that guides teachers and students through the steps of assembling the lab models, one teacher decided instead to engage her students in designing their own versions of the lab. In this case, the teacher adopted the essential structure and format provided in the recipe, but rather than giving it to the students in the form of explicit instructions, she used it herself as a basis for informing her coaching of the students. Second, the materials provided instructions and sample work for a calculation to establish a quantitative pattern in intensity that mirrors the visible pattern. In this case, the teacher relied on the lesson plan verbatim to lead students through each step of the calculation. Third, the materials provided support for a discussion that helps students connect the features of their lab models to the actual phenomena they represent. During this exchange,

A Case of Teaching as Design: Implementing the Global Warming Project

The Global Warming Project is a 10-week, inquiry-based classroom science project developed in collaboration with the Chicago Public Schools as part of the activities of the Center for Learning Technologies in Urban Schools (LeTUS), in which middle school students investigate the science of climate in the context of the controversial global warming debate. The project places students as advisors to the heads of state of several different nations, prompting them to learn about the issue as they respond to the various questions and concerns of these leaders. As expert scientists on the issue, the students must understand and be able to explain to the heads of state what factors affect climate. Once they do this, they must help the different nations of the world understand the local implications of global climate change and what they can do about it. Each team of students is responsible for advising one country and ultimately must present a proposal that offers a set of solutions that address the concerns of their country.

The Sun's Rays Lab

The examples discussed in this report center around a sequence of activities that investigate the angle of incidence at which sunlight reaches the Earth's surface and impacts the intensity of the light—and thus the energy—it receives. In the Sun's Rays Lab, students use pen lights and graph paper to model the Earth-sun relationship, measuring the areas cast by the light at different angles of incidence. With this data, students extrapolate the diminishing intensity that occurs as the light "spreads" over larger areas. Students also use the WorldWatcher data visualization software to explore geographic variation in the intensity of solar energy. For a more detailed explanation of these activities, see Brown & Edelson (1999) and Sherin, Edelson & Brown (2000).

the teacher seized upon a disagreement between two students to instigate a multi-day debate on competing interpretations of the model—a complete departure from the original design that nonetheless achieved compatible goals.

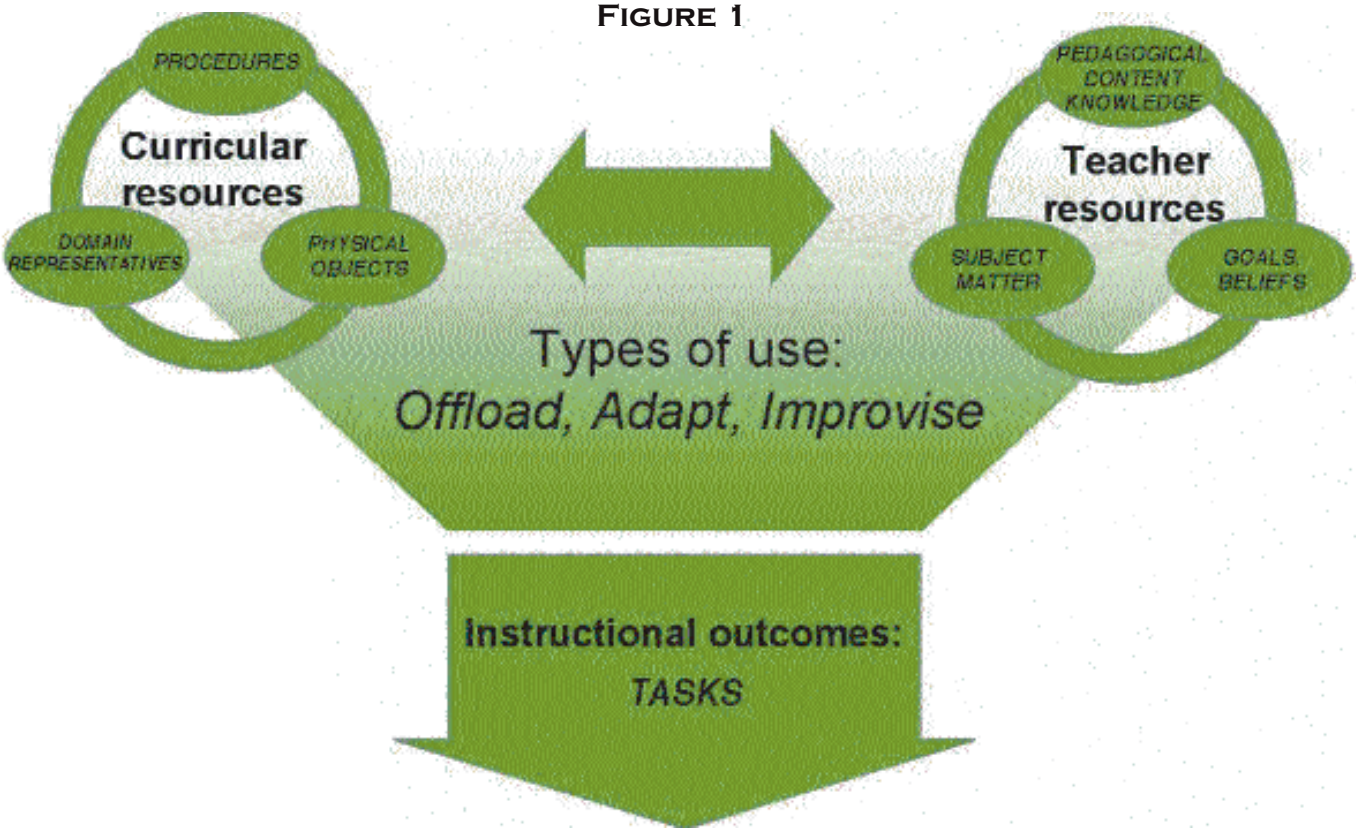
These and other examples suggest a scale that characterizes the different extents to which the teacher offloaded, adapted or improvised with the materials in the performance of instructional tasks. These three types of use describe the differential degrees in which responsibility for guiding instructional activity is distributable between the teacher and available instructional resources. These degrees of distribution lie along a spectrum. At one extreme, the teacher offloaded responsibility for guiding instructional activity onto the materials. In these cases, she relied on the materials to support aspects of instruction. At the other extreme, she improvised her own strategies for instruction with minimal reliance on the materials. In between, she frequently adapted the curriculum resources in ways that reflected contributions of both the materials and personal resources.

The teacher's use of the GWP materials is explainable as an interaction between her own personal resources (i.e., knowledge, skills and commitments) and the curricular resources (i.e., task structures, subject matter representations and physical tools). In analyzing the dynamic interactions of these factors, we developed the Design Capacity for Enactment framework (Figure 1), which supports the integrated study of artifacts and their use by practitioners. The framework provides a means of identifying and situating the factors that can influence how a teacher adapts, offloads or improvises with curriculum resources. Moreover, it highlights the interplay between the features of the curriculum design and the aspects of a teacher's own background that influence how these features are interpreted and used.

The Design Capacity for Enactment Framework

In the framework, "curricular resources" are the

Figure 1



representations of tasks, domain concepts and physical objects in the curriculum materials. In the GWP, these elements of the design took the form of procedures, representations of the science content and blueprints for configuring lesson materials. For instance, the Sun's Rays Lab involved an explicit procedure for conducting the lab, a representation for the Earth-sun relationship in the format of flashlights and paper and a blueprint for setting up the penlight model. Each of these features played a key role in supporting and constraining different forms of classroom activity. In the adaptation example given in the previous section, the lab procedure provided the teacher with a basic framework for conducting the lab. Though she decided not to give the procedure to her students, it provided a basic structure that helped her to guide the students in ways that met the intended goals. Similar patterns occurred with the representations of domain concepts and physical objects provided in the materials.

The nature of the teacher's own resources also played a key role in determining and constraining use of the curricular resources. The ways that she perceived and used the GWP was a function of her knowledge, skills and commitments. For instance, in the adaptation example provided above, the teacher's understanding of the subject matter, her familiarity with the experimental design

Adapt, Offload, Improvise: How Teachers Use Available Resources

The analysis conducted in this study suggests a scale that characterizes the different extents to which the teacher offloaded, adapted or improvised with the materials in the performance of instructional tasks. These three types of use describe the differential degrees in distributing the responsibility for guiding instructional activity between the teacher and available instructional resources. These degrees of distribution lie along a spectrum. At one extreme, the teacher who was the focus of the study offloaded responsibility for guiding instructional activity onto the materials. In these cases, she relied on the materials to support aspects of instruction. At the other extreme, she improvised her own strategies for instruction with minimal reliance on the materials. In between, she frequently adapted the curriculum resources in ways that reflected contributions of both the materials and personal resources. Spaced throughout this paper are examples of the three types of use.

Adaptations

Curricular adaptations are instances where teachers adopt certain elements of the curriculum design, but also contribute their own design elements to the implementation. Most instances of curriculum-use involve some sort of adaptation, be it deliberate or unintentional. Adaptations are characterized by a "shared" responsibility for curriculum design, distributed between the teachers and the materials.

Teachers may adapt curriculum materials for many reasons, including:

- To address particular student needs
- To conform to certain teaching styles
- To target specific learning goals
- To align with classroom circumstances

In one example used in this study, the teacher adapted the procedure of the Sun's Rays activity. While the materials provided a detailed recipe to guide teachers and students through the steps of assembling the lab models, the teacher decided instead to engage her students in designing their own versions of the model. In this case, the teacher adopted the essential structure and format provided in the recipe, but rather than giving it to the students in the form of explicit instructions, she used it as a basis for informing her coaching of the students. Nonetheless, the implementation largely followed the intended plan, with the teacher emphasizing the essential features of the model designs and appropriating the activity's overall rationale.

There were clearly identifiable factors that influenced this adaptation. For example, the teacher's stated goals of engaging her students in the creative process and of fostering experimental design skills played key roles in her modifications. Furthermore, her comfort with the experimental process (a hallmark of her teaching style) contributed to her ability to depart from the structured path described in the materials. At the same time, the materials provided key elements, such as a blueprint for a classroom model of an abstract geophysical phenomenon, which helped support her instruction. Thus, the contributions of the teacher resources and the material resources combined to produce a unique case of curricular adaptation.

process, her ability to use her knowledge to coach students through the design process and her desire to foster open-ended investigation all contributed to the particular ways in which she adapted the original procedure. Because of her familiarity with models and her experience in teaching students how to use them, she was able to perceive in the original design an opportunity for a model design task and at the same time was able to recognize the key features of the original model that needed preservation in order to meet the intended goals. Other teachers interpreted and used these features differently in light of their different knowledge, skills and desires.

The researcher applied this method of analysis to other instances where the teacher adapted, offloaded or improvised with the materials. Subsequently, the researcher applied this framework to two additional cases of teachers' use of the GWP. While we will not describe these analyses here, the following section highlights the findings and implications that emerged from cross-case comparisons using the design capacity for enactment.

Implications

The study suggests the importance of understanding teachers' pedagogical design capacity—that is, their ability to perceive and mobilize existing resources in order to craft instructional contexts. The notion of pedagogical design capacity (PDC) holds important implications for how teachers are prepared, how they gain access to appropriate materials and how researchers and school officials evaluate their enactments.

First, PDC suggests the potential benefits of professional development that is situated in customization tasks. In addition to support for learning subject matter and ways of teaching the content, which many have long advocated, teachers also require support in exploring which resources to use and how to use them. This latter aspect of professional development should help teachers link their instructional goals to the specific features and affordances of curriculum materials, and should support teachers in making the necessary design modifications required to achieve this alignment. Thus, teacher preparation and professional development might explicitly target the design skills required for effective use of instructional materials.

Second, PDC suggests that different teachers may require different types of resources depending on their knowledge, skills and commitments. For example, teachers with robust capacity to perceive underlying curricular goals might prefer open-ended resources which can be configured in different ways according to local circumstances, whereas teachers with less of such capacity might require materials that provide more explicit pointers to the uses and rationales of such resources, as well as more specified paths for putting them to use.

Offloads

Curricular offloads are instances where teachers rely significantly on the curriculum materials to support instruction, contributing little of their own pedagogical design capacity to the implementation. Offloads are shifts of curriculum design responsibility to the materials.

Offloads often occur when a teacher is unfamiliar or uncomfortable with the subject matter or pedagogical strategies recommended in a curricular unit and the curricular resources provide sufficient structure to support instructional activity. In one example used in this study, the teacher relied completely on a sample calculation provided in the lesson plan to lead her students through the steps of a mathematical calculation. In this case, the materials provided the bulk of the activity's substance, while the teacher served to communicate and clarify the steps of the lesson. While the offload lacked the instructional dynamism typical of this teacher's classroom, it provides an example of how the materials provided teachers with a valuable instructional resource that, given her lack of comfort and familiarity with the mathematical concepts, she would not have been capable of creating on her own.

Teachers may also choose to offload instruction onto curriculum materials for logistical reasons. In another example from the study, a teacher relied on student worksheets to structure the computer work of half of his class while he focused attention on supporting the other half in a conventional laboratory experiment. By offloading instructional responsibility onto the materials, the teacher created a multitasking environment that addressed his need to focus on a small group of students during a lab and provided a way for him to apportion valuable computing resources.

Third, PDC provides a way of evaluating how individual teachers perceive and mobilize the instructional resources described by the Design Capacity for Enactment framework. For example, it might help to account for similarities in teacher practice in the face of differences in resources and differences in teacher practice in the face of similar resources. Given their different knowledge, skills and commitments, teachers emphasized different aspects of the curriculum design – thus producing different instructional outcomes. At the same time, they typically engaged in similar processes of curricular adaptation, offloading or improvisation. The products of teachers' instructional designs in the GWP may have looked very different, but their ways of generating such outcomes shared important similarities.

One way to realize the potential of Teaching by Design is to rethink traditional modes of curriculum design, dissemination and use. Rather than designing curriculum materials as "one-size-fits-all" documents, efforts must be made to make visible the various ways they might be used to accomplish curricular goals. Furthermore, dissemination must occur in a context that supports teachers in making linkages between curricular resources, their own instructional goals and their students' needs. Professional development of this kind would serve not only to enhance teachers grasp of the utility of such resources, but also would provide a context for deepening professional dialogue about instruction and student learning. These efforts would dispel the notion that curriculum use is a matter of following recipes in order to realize a pre-conceived path of instruction. Rather, they would acknowledge an important reality of all instruction – that it is a creative process – and would open the door for designed artifacts to play a stronger role in stimulating instructional creativity. ■

Improvisations

Curricular improvisations are instances where teachers pursue instructional paths of their own design. In these cases, the materials may provide a "seed" idea, but the teacher contributes the bulk of the design effort required to bring the activity to fruition.

Improvisations generally occur when a teacher recognizes additional opportunity in a classroom situation and possesses the necessary knowledge and skill to depart on a new instructional path. For example, during a follow-up discussion to the Sun's Rays activity, one teacher in this study seized upon a disagreement between two students to instigate a multi-day debate on competing interpretations of the model—a complete departure from the original design that nonetheless supported the activity's overall objectives. Given that improvisations represent complete departures from the curriculum materials, they are generally deliberate.

Concluding Notes

This scale of offloads, adaptations and improvisations provides a means to classify the nature of the teachers' partnerships with curriculum materials by identifying differential contributions of instructional resources and distributions of design responsibility. In doing so, the scale is value-neutral, for it says nothing of the quality or effectiveness of each case, nor does it qualify the extent to which each example supports or departs from the curricular goals carried by teachers or materials.

NOTES

1) Available at <www.letus.northwestern.edu/projects/gw>.

2) This design partnership was part of the Center for Learning Technologies in Urban Schools (LeTUS), a collaboration involving researchers from Northwestern University and teachers from the Chicago Public Schools (additional LeTUS activities were coordinated with partners at the University of Michigan and Detroit Public schools).

3) The Sun's Rays Lab provides an investigation of how the angle of incidence at which sunlight reaches Earth's surface impacts the intensity of the light—and thus the energy—it receives. Students use pen lights and graph paper to model the Earth-sun relationship, measuring the areas cast by the light at different angles of incidence. With this data, students extrapolate the diminishing intensity that occurs as the light "spreads" over larger areas. For a more detailed explanation of this activity, see Sherin, B., D. C. Edelson, et al. (2000). Learning in Task-Structured Curricula. International Conference of the Learning Sciences 2000, Ann Arbor, MI.

REFERENCES

Ball, D. L. 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.

Ben-Peretz, M. (1990). The Teacher-Curriculum Encounter: Freeing Teachers From the Tyranny of Texts. Albany, NY, State University of New York Press.

Brown, M. W. and D. C. Edelson (1999). A Lab by Any Other Name: Integrating Traditional Labs and Computer-Supported Collaborative Investigations in Science Classrooms. Computer Supported Collaborative Learning, Palo Alto, CA.

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.

Cohen, D. K. (1990). “A Revolution in One Classroom: The Case of Mrs. Oublier.” Educational Evaluation and Policy Analysis 12: 327-345.

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

Elmore, R. F. (1979). “Backward Mapping: Implementation and Policy Decisions.” Political Science Quarterly 94(4): 601-614.

McLaughlin, M. W. (1976). “Implementation as Mutual Adaptation.” Teachers College Record 77: 339-351.

McLaughlin, M. W. (1990). “Rand Change Agent Study Revisited: Macro Perspectives and Micro Realities.” Educational Researcher 19(9): 11-16.

Norman, D. (1991). Cognitive Artifacts. Designing Interaction: Psychology at the Human-Computer Interface. J. Carroll. Cambridge, UK, Cambridge University Press.

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

Pea, R. D. (1993). Practices of Distributed Intelligence and Designs for Education. Distributed Cognition. G. Salomon. New York, Cambridge University Press.

Putnam, R. T. and H. Borko (2000). “What Do New Views of Knowledge and Thinking Have to Say About Research on Teacher Learning?” Educational Researcher 29(1): 4-15.

Remillard, J. T. (2000). “Can Curriculum Materials Support Teachers' Learning? Two Fourth-Grade Teachers’ Use of a New Mathematics Text.” The Elementary School Journal 100(4): 331-350.

Sherin, B., Edelson, D., & Brown, M. (2000). Learning in Task-Structured Curricula. Fourth International Conference of the Learning Sciences (266-272), Ann Arbor, MI.

Sherin, B., Edelson, D., & Brown, M. (to appear). On the Content of Task-Structured Curricula. In L. B. Flick & N. G. Lederman (Eds.), Scientific Inquiry and Nature of Science: Implications for Teaching, Learning and Teacher Education: Kluwer Academic Publishers.

Sherin, M. G. & Drake, C. (2003). Identifying Patterns in Teachers’ Use of Reform-Based Mathematics Curricula. Northwestern University.

Snyder, J., F. Bolin, et al. (1992). Curriculum Implementation. Handbook of Research on Curriculum: A project of the American Educational Research Association. P. W. Jackson, Macmillan Publishing Co.

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.

Spillane, J. P. (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.

Welch, W. W. (1979). Twenty Years of Science Curriculum Development: A Look Back. Review of Research in Education, vol. 7. D. Berliner. Washington DC, AERA. 7: 282-306.

Wertsch, J. V. (1991). Voices of the Mind: A Sociocultural Approach to Mediated Action. Cambridge, MA, Harvard University Press.

Wertsch, J. V. (1998). Mind as Action. New York, NY, Oxford University Press.

Wilson, S. M. and J. Berne (1999). Teacher Learning and the Acquisition of Professional Knowledge: An Examination of Research on Professional Development. Review of Research in Education. A. Iran-Nejad and P. D. Pearson. Washington, DC, American Educational Research Association. 24: 173-209.

Author Biographies

MATTHEW BROWN

Matthew Brown is a research associate with the Center for the Study of Learning, Instruction and Teacher Development (LITD) at the University of Illinois at Chicago. He received his PhD in the Learning Sciences program at Northwestern University where he worked on the development of the WorldWatcher geographic visualization software and the LeTUS Global Warming project, both efforts to support inquiry-based learning and teaching in K-12 science classrooms. A former classroom teacher, Dr. Brown's research examines the intersection of curricular reforms, classroom technologies and instructional practices. His dissertation, Teaching by Design, formed the basis for this article. In addition, Dr. Brown conducts research exploring the role of assessment practices in teacher development and the role of innovative technologies in the teaching of history.

DANIEL C. EDELSON

Daniel C. Edelson conducts research on the design of software, curriculum materials and teacher professional development to support inquiry learning. Trained as a computer and cognitive scientist, Dr. Edelson develops and studies software and curricula that are informed by contemporary research on learning, motivation and social/cultural dynamics. Since 1992, he has directed a series of projects exploring the use of technology as a catalyst for pedagogical reform in science education. As part of that research, he has developed numerous inquiry-based science curriculum units for Earth and environmental science courses from middle school through college and has published dozens of research papers. He teaches courses in the Computer Science Department and School of Education and Social Policy on the design and use of educational software, and he is currently the Chair of the Learning Sciences Program in the School of Education and Social Policy at Northwestern University. Dr. Edelson received his PhD in computer science from Northwestern University.

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