The Center for Learning Technologies in Urban Schools: A Case of Design-Based Research in Education

Laura D'Amico
Simon Fraser University
8888 University Drive, Burnaby, BC V3J 5J9, Canada
ldamico@sfu.ca

JULY 2005
Revised December 2005

Meta Study Case Report

With funding from
The John D. and Catherine T. MacArthur Foundation
The Spencer Foundation

All opinions and conclusions in this paper are those of the author and do not necessarily reflect the views of the funding agencies.

TABLE OF CONTENTS

ABSTRACT

The Center for Learning Technologies in Urban Schools is presented as a case study of the challenges and affordances of design-based research for creating productive relationships between researchers and educators. The case is organized around the three core activities which drove the Center's work: the design of inquiry-based curricula, the design of professional development to support those curricula, and the research conducted on these activities and their effectiveness for improving teaching and learning. In the course of describing these three key activities, the role of knowledge in the enterprise (who brings what knowledge to bear and how) and the influence of context (institutional, political, professional, and so on) on the Center's work will be raised. The case ends with a discussion of the capacity of design-based research to lead to useful and usable knowledge for educational improvement at large.

INTRODUCTION

Many educational researchers, practitioners, and policy makers have been troubled by the fact that findings from educational research so rarely lead to improvements in teaching and learning. In the past few decades, however, there have been a number of research and improvement efforts designed to bridge the gap between researchers and practitioners. Design-based research (or design experiments) is one promising approach to such efforts. However, work in this tradition has been criticized for creating "hothouse" reforms that are difficult to scale beyond a few classrooms. The Center for Learning Technologies in Urban Schools (LeTUS), a successful example of design-based research at a moderate level of scale, is described here as a counterpoint to these criticisms. LeTUS demonstrates that design-based research can be conducted with entire districts in a way that provides both substantive improvements in teaching and learning as well as advancements in theory related to both education and design.

Design-based research

Design-based research is an emerging form of educational research (Collins, 1999; Kelly, 2003), inspired by the work of researchers such as Ann Brown, Allan Collins, Roy Pea and Jan Hawkins and closely tied to the also emerging field of the learning sciences (Kolodner, 1991). While "pedagogical design has informed the development of theories of instruction for well over a century" (Cobb, Confrey, diSessa, Lehrer and Schauble, 2003, p. 9), design-based research as a recognizable and recognized tradition in education is fairly new. Because of its nascent form, the nature of design-based research is still somewhat under contention. Recently, special issues of both *Educational Researcher* (volume 32, number 1) and the *Journal of the Learning Sciences* (volume 12, number 1) were devoted to the exploration of just what design-based research is and what its value (and drawbacks) may be. In particular, some critics (and even adherents) of the approach worry that design-based research is being construed "as a kind of 'Swiss Army Knife' for scholars, capable of excelling at a wide range of research purposes" (Dede, 2004, p. 106) and that the term itself may be applied to any and all attempts to *design* learning environments regardless of the kind or quality of research connected with the study of that design. Allan Collins's definition for what he has called at different times, "a design science of education" (1992), "design experiments" (1992, 1999), and "design-based research" (Collins, Joseph & Bielaczyc, 2004), is a fairly well-bounded one and so will be used here. [1]

"Design experiments were developed as a way to carry out formative research to test and refine educational designs based on theoretical principles derived from prior research" (Collins, Joseph & Bielaczyc, 2004, p. 18). The innovations created by those conducting design experiments in the 1990s were often quite a substantial shift from typical teaching practice. Many included the use of technology, some of which was created specifically to support the kind of teaching and learning being promoted (e.g., Linn & Songer, 1991; Scardamalia & Bereiter, 1994). They often engaged students in forms of problem-solving or knowledge-building which are challenging and open-ended. The researchers, many of whom were trained in either cognitive science or experimental psychology, were not necessarily familiar with the complexities of daily classroom life. Likewise, the teachers had much to learn about the innovation and supporting technologies. As a result, researchers and practitioners worked closely together to iteratively rework the designs until they felt they were working well.

Research on the effectiveness of these efforts had to capture both evidence of student learning and also features of the design iterations that led to more successful implementations. Methods and instruments might include pre- and posttests of student learning, standardized achievement data, examples of students' work, video or observation notes of classroom activity, interviews with teachers and students, logs of computer use and activity, and responses to questionnaires measuring myriad aspects of student or teacher dispositions, beliefs, opinions, or motivations. Researchers were often stretched to learn new methods beyond their initial training to capture aspects of the new learning environments they felt were important (e.g. Brown, 1992). Even when the research was conducted in a single classroom or a few classrooms, the data collection and analysis often required several (or many) people with different sets of research skills to accomplish the work. Most important, the researchers were also the co-designers of the work. As a result, emergent findings could quickly be fed back into redesign. At the same time, the researchers did not have the kind of "distance" from the design that a typical evaluator would.

Design-based research thus has several typical characteristics (Collins, Joseph & Bielacycz, 2004): (1) it focuses on progressive refinement of an innovation, (2) it

[1] The term *design experiments* first emerged in 1992 in two seminal articles by Ann Brown (1992) and Allan Collins (1992) each describing the approach. The term design-based research has emerged in recent years to avoid confusion with experimental design, studies of designers, or trial teaching methods. However, many in the field continue to use the two terms interchangeably.

attempts to refine both theory and practice through this iterative design, and (3) the evaluation methods are multi-faceted and evolve as the design evolves. Some of the typical challenges include (1) lack of control of variables, (2) the generation of a huge corpus of data, (3) the need to coordinate the work of many people at once, and (4) the need to consider the interpretive bias of the researcher.

By the mid 1990s there were a number of successful design experiments that had been conducted in a single classroom or a small number of classrooms. Many of these designs could be considered "proof of concept" efforts aimed at answering two questions (1) "Can we really create classrooms that function in the ways our theories of teaching and learning indicate would be productive?" and (2) "If we can create such classrooms, do the children in them learn as well as or better than other children?" When the answer was "yes," funders began to push design-based researchers to move beyond these carefully nurtured "hothouse" settings to demonstrate that the innovations could be both scaled and sustained in a wider variety of contexts. The success of these initial efforts at scale varied greatly in the face of numerous challenges.

In general, when such projects attempted scale, the number of classrooms involved expanded far more than the number of researchers and other university-based support staff. It was no longer possible for the researchers to build and maintain the close working relationships they had when they were working with just a few teachers. Used to deep communication about ideas with their teacher collaborators, the researchers sometimes found it difficult to convey the substance of innovations to (much less co-design with) practitioners with whom they had a more tenuous connection. In some cases, this lack of connection led to concerns about "lethal mutations" of those innovations (Brown & Campione, 1996), that is, modifications to those innovations that disable or defeat their purpose. Nor could researchers be a frequent and substantive presence in all classrooms. This reduced the researchers' capacity to support the teachers in their efforts, to collect and analyze data on the results of that work for student learning and classroom activity, and to keep teachers involved in the design process. Some of those attempting to scale design-based research felt that the care and feeding of the "service" end of the work made it difficult or impossible to find time to adequately conduct research.

Coping with these challenges meant learning or creating new methods of collaborating and communicating with the education community and employing different kinds of research methods. A number of the early attempts at scaling design-based research made progress on one or both of these dimensions [e.g. The CoVis project (Gomez, Fishman & Pea, 1998); The Jasper project (Cognition and Technology Group at Vanderbilt, 1997)]. Building upon this previous work, the Center for Learning Technologies in Urban Schools included entire school systems in their design model.

The Center for Learning Technologies in Urban Schools

A collaboration between researchers at the University of Michigan and Northwestern University with educators in the Detroit and Chicago Public Schools, LeTUS endeavored to improve teaching and learning in middle school science classrooms through the use of learning technologies to support inquiry-based instructional methods. The focus of the design efforts was on the creation of educative curricula (Ball & Cohen, 1996) and supporting professional development systems that would embody strong use of technology in support of inquiry learning. They endeavored to craft designs responsive both to standards for science education and to the conditions of teaching and learning in urban contexts. In addition, they hoped the innovations they introduced would create opportunities for the district to rethink its own work. Thus, the "design" would include not only the creation and refinement of technologies and curricula but also potentially changes to the district's operating procedures that would make such instruction viable in classrooms.

Their work can be considered a modest attempt at scaling design-based research. During the six years the Center was in existence (1997-2003), somewhere between 20% and 30% of middle school science teachers and key district staff participated in the work. Together, they created fourteen curricular units, built a cadre of teachers with expertise in inquiry-based science in both school districts, fostered improvements in science achievement for middle-school students who experienced the work of these teachers, and crafted enduring relationships between the researchers and educators. While funding for the Center itself is now over, the work has led to new funding streams for expanding the curricula, refining their theory and procedures for creating inquiry-based curricula (e.g. Reiser, Krajcik, Moje & Marx, 2003), and continuing the relationship between the researchers and educators in both districts. It has also led to contributions to the field's evolving understanding of design-based research, its possible permutations, strengths, and limitations (e.g. Edelson, 2001; Fishman et al., 2004).

The legacy of LeTUS, at least in the short term, is an impressive one. The number of papers, follow-up grants, and real changes to teaching and learning in the two districts are a considerable achievement. But perhaps one of the most interesting contributions LeTUS can make to the field is its ability to illuminate the multi-faceted role of "design" within design-based research. "Design" was not just a mode of research, it was the medium of collaboration in LeTUS. Decisions about what to design and how to design it became a task space that brought people together, drew upon their various expertise, and anchored their negotiations for how to proceed. Most important, the activity of designing, and especially designing with others, became a huge source of personal and professional development for researchers and educators alike. Thus, design-based research as practiced in LeTUS contributed to the knowledge base of the field of education at large in several ways: through research findings about the efficacy of the instructional designs produced, through the generation of curricula, research instruments, and design procedures that can be used elsewhere, and through the capacity built within the participating educators and researchers to continue and expand on work of this nature.

The case is organized around the three core activities which drove the Center's efforts: the design of inquiry-based curricula, the design of professional development to support those curricula, and the research the Center conducted on these activities and their effectiveness for improving teaching and learning. In the course of describing these three key activities, the role of knowledge in the enterprise (who brings what knowledge to bear and how) and the influence of context (institutional, political, professional, and so on) on the Center's work will be raised. In particular, while aspiring to many of the same goals, the two sites involved in the center, Chicago and Detroit, took different approaches to the work. As will be seen, the needs and structure of each district as well as the organization and expertise of each research team played a significant part in how the work at each site proceeded. Comparisons between the two approaches reveal insights into how the general aims of LeTUS were adjusted to local capacity and needs. The case ends with a discussion of the capacity of design-based research to lead to useful and usable knowledge for educational improvement at large.

DATA SOURCES

The work presented here is a retrospective case study of the Center for Learning Technologies in Urban Schools. Sources of data collected and reviewed include: interviews conducted with a variety of members of the LeTUS community, grant proposals and/or abstracts related to the work, a number of the central papers and presentations made by the participants, a subset of the curriculum produced by the Center, curriculum vitae for a number of the core researchers involved in the center, and the LeTUS website.

Data were collected in two waves. In 2003, LeTUS was one of a number of projects reviewed as possible candidates for a meta-study of productive relationships between researchers and educators. During this initial phase, referred to as the "due diligence" phase by the meta-study researchers, data collection and analysis focused on creating a clear description of the projects being considered and the feasibility of fuller study of them. A report was written based on the findings from these data and then a subset of the original cases selected.

The due diligence data collection for LeTUS included a trip to both sites (University of Michigan/Detroit Public Schools and Northwestern University/Chicago Public Schools) in June of 2003 to conduct one-on-one interviews with eight key participants in the study. These included the co-director from each university (Louis Gomez and Ron Marx), two other tenured faculty from each university (Brian Reiser and Joe Krajcik), a research or non-tenured faculty member from each university (Greg Shrader and Barry Fishman), and the central coordinator for professional development from each site (Lou-Ellen Finn and "Barbara Steel"[2]). Interviewees were asked about the goals of the Center, their strategies for meeting those goals, and the ways in which they determined whether they were successful in meeting them. They were also asked about the kinds of knowledge and expertise that were critical to making an endeavor like this work and how the organization learned from its efforts. These interviews, augmented by a review of the Center's website and a handful of papers and presentations, served as the core data for the due diligence report.

LeTUS was chosen as one of the cases for further study, so a second wave of data collection was conducted to deepen the case. The data collection in this phase focused on deepening the understanding of how the LeTUS collaboration functioned, gaining a

[2] In accordance with Detroit Public School's regulations for research conducted in their district, all DPS employees will be referred to by pseudonym.

clearer grasp of the educators' perspectives on the work, understanding the contributions the work was making to both research and practice, and unpacking the influence of institutional contexts on their efforts. The data collected included eight focus group interviews conducted in June of 2004 — one each of teachers, teacher leaders, graduate students, and researchers at each of the sites, for a total of 33 participants. In addition, individual interviews were conducted with the Dean at both Schools of Education and with the lead district contact in each school district (the Chief Academic Officer for the Detroit Public Schools and the director of the science component of the Chicago Mathematics and Science Initiative). Finally, both research co-directors (Ron Marx for University of Michigan and Louis Gomez for Northwestern University) were interviewed again individually.

In addition to these interviews, an effort was made to collect a listing of papers and presentations as well as funding sources. This list was based upon the individual vitae of a number of the researchers involved in LeTUS, as well as a search of educational indices and the "agenda" for the conferences where the researchers present most often — AERA, ICLS and NARST. Core papers both about LeTUS and about design-based research more generally were collected and reviewed[3]. Finally, examples of the LeTUS curricula were collected and reviewed.

My own experiences as a researcher in the field of Learning Sciences served as a lens through which these data were viewed. I am a graduate from the Learning Sciences Program at Northwestern University. I began my graduate work in 1992, the first year that the Learning Sciences program was in existence. I left the university in the summer of 1997 just before the LeTUS work began. My dissertation research was done in the context of the Learning through Collaborative Visualization (CoVis) project, one of the precursors to LeTUS. I knew a number of the graduate students who participated in the early years of LeTUS, and my thesis advisor, Louis Gomez, was the co-director for Northwestern. Thus my own experiences as a graduate student doing similar kinds of work and my familiarity with the people and institutions involved serve as an additional source of insight.

PROJECT BACKGROUND AND GOALS

The Center for Learning Technologies in Urban Schools (LeTUS) was a partnership forged among the University of Michigan, the Detroit Public Schools, Northwestern University, and the Chicago Public schools to understand how "learning and collaborative technologies can serve as a catalyst in support of systemic change efforts in urban schools in the United States" (Gomez, Marx, Soloway, Schank, Gray $ Burgess, 1997, p. 1, LeTUS proposal to NSF). It was one of several Centers for Research on Learning and Teaching (CRLT) funded by the Directorate for Education and Human Resources (EHR) of the National Science Foundation (NSF) through their Learning and Intelligent Systems (LIS) program in 1997.

---

[3] The number of theses, conference papers, technical reports, and publications produced by the LeTUS researchers is extensive. Only the subset cited in the reference section of this report was reviewed closely.

The core concern of this partnership was the fragile and one-dimensional nature that most implementations of innovation take when attempts are made to scale them beyond a few carefully nurtured classrooms, especially when such innovations are attempted in urban settings. In particular, the LeTUS collaborators felt that such innovations are often "not sufficiently sensitive to the actual context in which the innovation is to be used, and do not attend to the many problems associated with school restructuring, all of which need to be addressed for lasting change" (Gomez et al., 1997, p. 2). LeTUS proposed to tackle this problem by using a *client-focused* research and development effort in which the contexts of teaching and learning in the Chicago and Detroit Public Schools would shape the Center's work. "We weren't going to just manufacture solutions and take them to the district and try to sell them on the solutions but rather, we would work in problem solving partnerships with the district" (Reiser interview, June 5, 2003). At the same time, they believed the introduction of innovations would *problematize* each district's work, challenging old practices and creating a dilemma around which organizational thinking, learning, and change could be catalyzed. They hoped, therefore, not only to design, redesign, or adapt technological innovations to meet the districts' needs, but also to reshape district policy and practices to better support the implementation of those innovations in classrooms.

The technologies to be introduced to the urban districts in question were those that could be useful for improving teaching and learning in middle school science classrooms. The researchers involved in writing the original LeTUS proposal all had a history of creating and integrating technology into schools in the service of supporting inquiry-oriented approaches to science education. While the science to be learned was always a critical goal in this early work, in many (though not all) cases, they considered their scholarly contributions to be about the ways in which the technology could be designed and used to meet that goal. Indeed, both the name of the Center itself and the thrust of the argument in the original grant proposal reflect this focus. Science was the context, but the use of technology to improve learning was the goal. However, an interesting and important shift in priorities occurred as the university teams began working closely with district leadership. The design of curriculum and professional development to support its enactment became driving foci of the work and core referents that defined their collaboration.

In the end, most of the interviewees described more than one goal for LeTUS: foster inquiry-oriented science instruction, incorporate technology to support student learning, explore the organizational and policy supports necessary to make such instruction work throughout entire school systems; and forge new and productive relationships between universities and K-12 educators. The design and provision of curriculum and professional development became their vehicle for meeting these goals. Their research then focused on documenting the challenges they faced (e.g. Fishman, et al., 2004), the effectiveness of their efforts (e.g. Marx et al., 2004; Herman, Mackenzie, Sherman & Reiser, 2003; Herman, Mackenzie & Rose, 2003; Geier et al., 2004; Rivet & Krajcik, 2004), and strategies that proved useful (e.g. Edelson, 2001; Fishman et al., 2003, March; Shrader et al., in review).

By all accounts the efforts of LeTUS have been a successful and satisfying collaboration for all participating groups. In the rest of this section, some of the pre-conditions that enabled this success are explored.

Pre-LeTUS History and Conditions

The LeTUS collaboration appears to have been generally less rocky for the contributing organizations than some earlier partnerships, such as ATLAS (Hatch & White, 2002), have been. This is not to say that the work always went smoothly. However, there were a number of pre-conditions that may have made their joint work proceed in a relatively satisfactory way. First, the standards and accountability movement in conjunction with the explosion of the internet created a political and social context welcoming of the inquiry-based, technology-supported science learning championed by LeTUS. Second, the researchers involved had similar, though not identical, theoretical commitments and practical experiences with respect to the use of technological tools to support science learning. Some knew each other from previous work and were friends. Moreover, both research teams had already developed working relationships of some kind with the local urban district — Northwestern with Chicago Public Schools and University of Michigan with Detroit Public Schools. These circumstances facilitated their collaboration with one another and the districts. Third, each of the two districts had received grants for Urban Systemic Initiatives from NSF (1994-1999), the goals of which dove-tailed nicely with the Center's proposed work. At the same time, the district policy and organizational structures around curriculum, testing, and professional development in each school system were quite different. The previous relationships and similar sets of goals among the group members paved the way for them to create a productive working relationship among the four institutions, while the differing district contexts required unique strategies of implementation in each of the two cities.

National context

There were two important shifts in the national context with respect to science education in the 1990s that paved the way for LeTUS — the standards movement and the explosion of internet technologies. In the early half of the decade, national standards for science education emerged (e.g., American Association for the Advancement of Science, 1990; 1993; National Research Council, 1996) and the development of students' proficiencies and habits of mind related to scientific inquiry were core goals of these standards. As a result, researchers and educators interested in inquiry-based forms of teaching and learning, such as the LeTUS participants, found support for their efforts from these documents.

As the standards movement in general gained momentum, most states created standards documents of their own, often based upon or informed by the national ones. In 1996, only 14 states had standards in the core subjects of English, mathematics, science, and history/social studies. However, other states soon followed, and the standards movement quickly became linked to assessment. By 2001, nearly every state had assessments intended to measure student achievement with respect to state standards in all four core subject areas (Achieve, Inc., 2001). At the same time these changes in standards and testing were occurring, a push toward holding the school systems more accountable for students' performance began to build. By 2001, nearly all states provided school report cards (44), almost half used testing for the purposes of either promotion or graduation (24) and a few sanctioned low performing schools (13) (Achieve, Inc., 2001). The *No Child Left Behind Act* has continued this trend by linking state access to federal dollars not only to student achievement, but to *improvements* in achievement as measured by state tests (U. S. Department of Education, 2002).

Thus, while the early portion of the standards movement created a favorable context for pursuing inquiry-based curricula, the more recent push toward accountability linked to standards has created an imperative that such instruction provide demonstrable results. The Center for Learning Technologies in Urban Schools (1997-2003) landed in the midst of this trend, beginning after the standards movement was in place and just as the accountability push was gaining steam. The standards provided a defensible rationale for the participants' desire to pursue inquiry-based instruction, but the building accountability context made it clear that they would need to demonstrate learning in politically viable ways.

The second important shift occurred in the mid-1990s. Internet access and computer use exploded across the nation. Small personal computers had been affordably priced since the 1980s and had made their way into both homes and schools. Use of these tools, however, was restricted largely to the technologically savvy until the early to mid 1990s. Moreover, prior to about 1994, the internet was largely used by government, academic and research institutions, and to some extent high-tech companies. A confluence of events brought computing into the mainstream.

User friendly graphic interfaces for email emerged, protocols for sending email became simpler, and email/bulletin board/conferencing systems aimed at the general public (e.g. AOL) became connected to the internet backbone. Second, a technology for facilitating access to documents across the internet — the World Wide Web — was developed. The combination of email and information access in a user friendly format suddenly made computers much more accessible to the general public. (The increasingly complex and visually compelling nature of computer games didn't hurt either.) The "dot-com explosion" soon followed and with it came a renewed concern that students must be technologically proficient to survive in the new information society. Not surprisingly, a huge push to network schools soon followed. However, once all the computers and internet access were in place, many educators were still not sure what to do with them. To a large degree this remains true today.

Research and development context

The work of the researchers from University of Michigan and Northwestern University tended to slightly precede these national trends. As a result, they had some tangible strategies to offer K-12 educators. In the late 1980s and early 1990s they began to explore the possibilities of project-based science supported by learning technologies. They were early pioneers in the use of computers to support science learning and had acquired network access for their participating classrooms far before most schools were wired. This early work put them in a position to capitalize on new research funding streams aimed at supporting schools' use of technology in the context of standards-based instruction.

The *Enhancement of Project-Based Science: The Project Support Network* (PBS) project (1991-1994) run by the hi-ce group out of University of Michigan (Joe Krajcik, Ron Marx, Elliot Soloway and Phyllis Blumenfeld)[4] explored how to make projects as an instructional form more feasible and manageable by teachers and studied teacher change in the context of implementing science projects (Krajcik, Blumenfeld, Marx, & Soloway, 1994; Krajcik et al., 1998; Marx, Blumenfeld, Krajcik & Soloway, 1997). This project began with a review of the literature as it relates to project-based science and the formation of some basic principles for what good project work is like. The researchers then tried to help teachers understand project-based learning through these general principles and some examples of teachers doing activities that incorporate those principles. Supported by funding from a series of related grants, the group also developed a suite of computational tools called the Investigators Workshop to support students' inquiry. "These tools support[ed] data collection, data visualization and analysis, dynamic modeling, planning, Web publishing and information gathering from the University of Michigan digital library and the Internet" (Blumenfeld et al., 2000). They then worked closely with teachers to see how their principles for project-based science, along with the software tools at their disposal, could be implemented and contextualized to meet the needs of teachers and students in classrooms.

Around the same time, Soloway also worked with Roy Pea and Louis Gomez, both at Northwestern University, to create the Learning through Collaborative Visualization (CoVis) Project (1992-1998). CoVis aimed to improve teaching and learning on geoscience topics in high school classrooms. Like the group at University of Michigan, they had a commitment to a project-based approach to science instruction, supported by computing and telecommunications technologies (Pea, 1993; Pea & Gomez, 1992; Gomez, Fishman & Pea, 1998). In particular, they were experimenting with the development of data visualization tools for students that would enable them to explore phenomena like weather patterns and climatic change. They incorporated the use of desktop teleconferencing to support collaboration between school sites and with science experts. And they developed an on-line Collaboratory Notebook to guide students' data collection and reflection as well as provide additional support for cross-site collaboration. The project had two phases — a two year "proof of concept" phase in which they worked closely with six teachers in the Chicago suburbs, followed by a four year expansion phase in which the project grew to include nearly 150 teachers from across the United States.

At the same time, Brian Reiser at Northwestern University was developing a new research program that expanded upon his earlier work on student problem solving and explanations. The core of this work was the *Biology Guided Inquiry Learning*

---

[4]Blumenfeld, Krajcik, Marx, and Soloway worked together on several grants related to science and technology. They eventually decided to give themselves a name, "Center for Highly Interactive Computing in Education (hi-ce). Others have since joined them. For a full list of the key players in the Center see Appendix A.

Environment (BGuILE) Project (1995-present). Reiser and his students constructed software tools to support students' efforts to explore and make sense of primary data about biological phenomena and to construct and communicate persuasive explanations of them (Reiser et al., 2001; Sandoval, 2003; Tabak, 2004).

Given this background, it is not surprising that the endeavors at both institutions shared some common goals and perspectives. Both groups expressed interest in improving scientific understanding and literacy by giving students more experience with the *practice* of science — in particular engagement in open-ended investigations. Both groups believed technological tools could provide strong support for students' comprehension of scientific concepts and phenomena. Finally, both groups believed in the power of collaborative work for supporting student learning and teacher change. These similarities gave them a strong common ground with which to begin their collaboration.

District context

The educators in the two LeTUS districts were also working hard on issues related to inquiry-based science and technology integration prior to the Center's formation. In the mid-1990s the National Science Foundation crafted Urban Systemic Initiative and State Systemic Initiative programs aimed at helping states and urban districts come up to speed with new standards in mathematics and science as well as emerging technologies to support student learning in these areas. Both Detroit and Chicago Public Schools had received funding under this program to establish Urban Systemic Initiatives (USI).

The USIs (1994-1999) were still underway when the LeTUS grant was written in 1997. The goals of the initiatives were similar in both cities — to improve scientific and mathematics literacy, increase students' knowledge of mathematics and science fundamentals, and enable a greater number of students to pursue careers in mathematics, science, and technology. However, the pursuit of these goals differed due to discrepancies in the organizational structures and accountability contexts of the two districts.

The Detroit Public Schools is a relatively centralized school system, serving over 160,000 students. District offices in each subject area provide both curricular direction and professional development support. Michigan has state mandated tests in science tied to their educational standards, called the Michigan Benchmarks. The tests and related Benchmarks have strong currency within the system as a whole. The state test — the Michigan Assessment of Educational Progress (MEAP) is given in the subject of science in grades five and eight. The city also administers the Terra Nova (CTB/McGraw-Hill) each year in the subjects of reading, mathematics, social studies, and science to all students in grades one through eight (Steel, email and phone conversation, August 27, 2003). These tests are seen as important achievement indicators by both principals and district leaders.

Not surprisingly, the efforts of Detroit's Urban Systemic Initiative focused on interpreting the Michigan Benchmarks and supporting teachers' efforts to provide instruction that would help their students meet them. They created a curriculum framework that lays out which of the Michigan Benchmarks teachers should focus on throughout the year. This framework consists of a set of topical guidelines along with suggested activities and resources (including a city-adopted textbook) that teachers might use (Steel interview, June 4, 2003). This structure means that all (or most) science teachers in a given grade are covering the same topics simultaneously and with many of the same resources.

In contrast, Chicago Public Schools is a highly *de*centralized system, serving nearly three times as many students (over 435,000). In 1988 a policy of site-based management was implemented to give decision-making control, including choices about curriculum, to local school councils. The district did establish a set of *Chicago Academic Standards and Framework* just prior to the inception of LeTUS. Educators involved in LeTUS took these standards and frameworks seriously and so they had some authority within the system. However, in the end, all curriculum choices were under local control and school choices varied greatly. Across the district, teachers might not be covering the same topics in a given year, much less in the same order or using the same resources to do so. One study done by the district found more than 80 different mathematics textbooks being used throughout its 500 elementary schools (Northwestern researchers focus group, June 18, 2004). Such curricular diversity makes systemic efforts for both reform and professional development challenging.

Moreover, Chicago considered its pressing needs to be basic literacy and numeracy, a fact reflected in its accountability system. CPS assesses the reading and mathematics proficiency of all students in grades one through eight every year using the Iowa Test of Basic Skills (ITBS). These test scores, along with those from the Illinois Standards and Achievement Test in reading and mathematics given in grades 3, 5 and 8 "are the ones CPS cares about the most" (Finn email, August 7, 2003). Schools have the option of giving their students the ITBS in science, but as they must pay for this additional testing out of their own budgets, most do not. Illinois now assesses students in science in grades four and seven, but when LeTUS began it did not. Once those tests were in place, the Chicago Public Schools administration did not scrutinize the scores as closely as it did those in reading and mathematics.

Chicago's Urban Systemic Initiative (CSI) was shaped accordingly. The program focused on providing schools and teachers with professional development, but that professional development was largely divorced from curriculum. The initiative did not adopt a particular curriculum or even make suggestions or recommendations to schools about which curriculum to adopt. As a result, "It had no instructional vision or coherence, particularly around science" (Lach interview, October 6, 2004). In fairness to the CSI personnel at the time, the site-based management policy made creating and spreading a vision problematic. It is not clear that such an effort would have been welcomed or considered appropriate.[5] This combination of circumstances would make mounting a systemic improvement effort in science challenging for the LeTUS collaborators.

---

[5] Toward the end of the LeTUS grant, there was a change in district leadership. A new initiative, the Chicago Mathematics and Science Initiative (CM&SI) replaced the CSI. Funded largely out of the

Each university team had at least some experience collaborating with schools, classrooms and district leadership in its local district prior to LeTUS. Nineteen Chicago schools participated in the scaling phase of CoVis, while hi-ce had worked with Detroit schools and classrooms since 1991 via both the PBS and *Community Science Connections* projects. These previous collaborations had proven useful and shown the district-university pairs to have similar beliefs with respect to the value of inquiry and technology for improving science education. Thus there was interest in both districts to pursue the collaborations further. But, as one might expect, those collaborations had a slightly different flavor in each location.

Implications of context and prior experience for the work of LeTUS

These contextual conditions and constraints had a number of implications for the way the LeTUS work progressed. First, the national focus on standards and accountability led to a standards base for their curriculum design, while the *No Child Left Behind Act* led to research designs that included both politically important test measures and the use of control groups, particularly toward the end of the grant. Second, the prior work of the researchers and prior collaborations with each district led to a relatively productive working relationship between the collaborators at all four sites. However, the differences in the district contexts, combined with differences in the structure and history of collaborative work in each research team, led to very different strategies for the design activity in each city. In general, the hi-ce/Detroit Public Schools team took a more centralized approach to the curriculum design as well as the design and provision of professional development than did the Northwestern/Chicago Public Schools team. The final designs themselves also differed. Those differences in the professional development offerings in each city seem particularly tied to the district contexts. The deepest component of the professional development offerings provided by the Detroit branch of LeTUS was integrated in the school system's professional development infrastructure, while the deepest component provided by the Chicago branch was in the form of graduate course work provided through Northwestern University. As the Center's designs for curriculum, professional development, and research are explored in more depth in later sections of this report, each of these implications will be revisited.

Building a working relationship: Core tasks of the LeTUS collaboration

In addition to sharing a lot of intellectual ground, the group also contained a large number of people who were highly capable of working with others.[6] Interviews with both individuals and focus groups indicated a genuine and heartfelt respect for one another among the myriad district leaders, teachers, researchers, graduate students, and staff participating in the work. As one interviewee said, "At the end of the day, we worked

---

district's operating budget, the new CM&SI is far more proactive about curriculum decisions. Using a combination of incentives (e.g. professional development support and funds for materials) and sanctions (schools on probation *must* use the CM&SI recommended materials), CM&SI endeavors to encourage the local school councils to choose its curriculum recommendations (Lach interview, October 6, 2004).

[6] See Appendix A for a list of key members of the LeTUS team for each of the member institutions.

well together because many of those involved are genuinely nice people" (paraphrase from Gomez phone conversation, September 8, 2003). Moreover, some of the participants caution that while they did evolve strong strategies for maintaining cordial and trustful relationships between the universities and districts, to a certain extent the evolution of those strategies was somewhat accidental. They were fortunate to have practitioners involved who were willing to speak their minds. Ron Marx, the co-director for University of Michigan, describes the strength of their work with Detroit Public Schools as based in honesty:

> It was largely a function of some really fabulous people who were willing and able to be blunt with each other, to call each other out when the other group is doing something untoward or unthinking and a group that was blunt and frank and candid, yet supportive and encouraging and committed. I can't overestimate the importance of that. And really, the people on the Detroit side responsible for that were Amelia and Barbara, really, truly amazing people (Marx interview, October 1, 2004).

Still, the success of the LeTUS collaboration was not simply based on a serendipitous collection of friendly people with similar backgrounds. Significant work was done to build upon these fortunate conditions and maintain their working relationship — both between the universities and between each university-district pair. In particular, the researchers were cognizant of the traditional boundaries and power structures that usually create tensions between researchers and K-12 educators. They were determined to build "multi-tiered trust relationships across the levels of [the university] organization as a project and the levels of the school system in both cities" (Gomez interview, June 6, 2003). Moreover, in order to have sustained relationships with these districts, they felt they could not *just* work with their "friends" — teachers and administrators whom they knew from prior work — but also must engage new people in the endeavor. "We explicitly as a strategy in the building of the Center wanted to create relational trust with people we didn't know prior to the work" (Gomez interview, June 6, 2003). To do so, they needed to establish regular practices that respectfully engaged Detroit and Chicago educators in the work and began to break down the traditional power relationships between researchers and educators that might hinder collaboration.

As a basic strategy, they began by meeting on the educators' ground. This entailed physically holding their meetings in the educators' offices or schools, but more importantly starting each discussion from the educators' framework — with their problems and their expertise as the anchor. As one district leader put it, "It becomes our work when we are seen as collaborators and have ideas and opinions that are valued from the perspective of the people that deal with these things every day, then are able to provide information and have it accepted from that perspective" (Gray interview, June 14, 2004). As mentioned earlier, the collaborators wanted LeTUS to be a *client-focused* research and development effort, anchored in the needs and problems identified by the district. To maintain this client-focus, they engaged the district leadership in the management and direction of the work.

The Center was conceived of as a partnership between four equal institutions, each of which participated in its direction and management. Thus, there were four co-directors: Louis Gomez representing Northwestern University, Clifton Burgess representing the

Chicago Public Schools, Ron Marx representing University of Michigan and Amelia Gray representing the Detroit Public Schools:

> It was clear that we couldn't succeed at this if the researchers were the directors and the people in the districts were sort of the users of the stuff. The only way to get viable usable products out of this, and usable for K-12 people and for researchers, was to have a coordinated team. We needed the input from the district and as much as possible, the designing endeavors that came out of this, the R and D, had to have a balance of K-12 and higher ed people on it (Marx interview, June 4, 2003).

Initially, these four served as the central management team for the Center and met frequently, either in person or over the phone via conference calls. Due to the very different working styles and paces of university researchers and district leaders, they found regular meetings of the four coordinators hard to maintain. Instead, as the work progressed, each district/university team collaborated closely and then the two university teams served largely as the coordinating vehicle between the two cities. However, those initial meetings were crucial ones as they set the stage for the direction LeTUS would follow. In particular, it was these early meetings that led to the decision to focus the collaboration on curriculum design.

"We didn't propose LeTUS as a curriculum project to the NSF and I don't think we knew how central a role curriculum was going to play," notes one researcher (Reiser interview, June 5, 2003). However, they did know early on that they were going to need to anchor their relationship in productive tasks. While the grant proposal specified they would work as a problem-solving team, it did not specify how they would focus that work. "What's going to be the motivation to get really talented and busy teachers together and really talented and busy researchers together with the really talented and busy teachers? Let's do it when there's a real job to do and let's make the conversations around work that needs to get done" (Reiser interview, June 5, 2003). These collaborative teams would be called "work circles" (modeled somewhat after the idea of "learning circles") and Dr. Gray gave them their job to do — build curriculum.

Curriculum had always been a significant vehicle for Gray in her work supporting teachers. She has been with the Detroit Public Schools for more than thirty-five years. She started as a science teacher, but eventually moved into a role of instructional specialist where her job was to help teachers in their classrooms. Then she became a supervisor (with oversight as well as support responsibilities) in science instruction. This was followed by a number of moves up within the administration, starting with direction of mathematics and science instruction, but ending with the position of Chief Academic Officer for the district. She has spent considerable time in both her own and other teachers' classrooms. "Some of the things that I would see in classrooms as a supervisor signaled to me that teachers were doing a good job, but they needed more innovative strategies and we would build lessons. To have the University work with us in the development of these tools was just an ideal situation" (Gray interview, June 14, 2004).

The researchers may not have thought of themselves as curriculum producers, but Gray did. "They were. They were looking at extended projects and working to make sure that teachers understood how to … situate the learning." A review of their pre-LeTUS work indicates that all three groups had begun to experiment with curriculum-like tools just before they came together to write the LeTUS grant. These materials might include outlines of project activities or descriptions of basic principles related to project-based science. They were designed largely to help researchers communicate with their teacher collaborators and provide some scaffolds for teachers doing inquiry-based science instruction. Some were essentially joint working documents created by researchers and close teacher collaborators, others were meant to disseminate their ideas to a broader teacher audience. None of them had the kind of thorough treatment of commercial curriculum and could probably best be described as "proto-curricula".

These proto-curricula were a natural outgrowth of the researchers' prior work and their efforts to include more teachers in that work. As one researcher described this process with respect to his own research, "We moved outward from thinking about what do kids do with software to learn important concepts, to thinking about what the teachers need to do to setup the activities so students will learn important concepts, to how do we write this all down in order to communicate it to other teachers who we haven't talked to directly and how do we design professional development around this curriculum" (paraphrase from Reiser interview, June 5, 2003).

Gray believed this early work was important, but felt that the researchers needed to make what they had learned from it more concrete. "The concern of our teachers on a day-to-day basis was, 'How do I manage that within the context of what we have to do day-to-day, given that we have a state that assesses [us] and that all the students, teachers, and buildings are held accountable?'" (Gray interview, June 14, 2004).

> In some of our first meetings, the administrators and teachers both in Chicago and in Detroit said, "You want us to use technology in our teaching to help kids learn? Then we need to have curriculum that embeds the technology, otherwise, we can't do it. … You want us to do inquiry. You want us to use technology. We need examples. We need the materials" (University of Michigan researchers focus group, June 14, 2004).

From Gray's point of view the project needed to shift its focus from questions of how to make learning through inquiry *happen* (a 'proof-of-concept' question) to how to make inquiry-based learning fit within the context of a standards-based accountability scheme (a scaling question)? What are the time and pacing considerations? How can the project make the inquiry work match up with the standards and tests to which teachers are accountable?

This was an idea that resonated well with the members of LeTUS. In reflecting upon their earlier work, the researchers noted that very few teachers were able to successfully implement project-based science with just a few principles to guide them. To do so requires a clear vision of what a constructivist classroom where children do inquiry and use tools to support their investigations looks like. It also requires strong content knowledge and pedagogical content knowledge related to the science topics being covered. The creation of curriculum materials might help scaffold teachers into the use of inquiry techniques. Moreover, to design those materials effectively, the curriculum teams would need people with knowledge of each district's standards and accountability framework, as well as those with knowledge and expertise related to inquiry-based teaching and learning technologies. It was a natural vehicle for pulling the practitioners and researchers together.

Soon, curriculum — which was initially seen simply as a vehicle for communicating about and supporting teachers' use of both inquiry-based teaching methods and learning technologies — became a collaborative anchor. As work moved forward from initial curriculum design and piloting, professional development became a second collaborative anchor. Research was largely the responsibility of the researchers. However, to some extent, it became a third collaborative anchor as practitioners' insights and experiences were funneled into the design effort and their needs for research findings were taken into account in the research and reporting designs. To all of these tasks — curriculum, professional development, and research — both researchers and practitioners contributed knowledge and expertise. The result was further knowledge about research, practice, and the support of the collaboration itself. In the sections that follow, the details of the three core aspects of the LeTUS collaboration — curriculum, professional development and research — are each discussed in depth.

COLLABORATIVE DESIGN: BUILDING AN INQUIRY-BASED CURRICULUM

Scientific inquiry within K-12 classrooms can take many forms. At one end of the spectrum, students may conduct fairly traditional labs. These mimic the steps of an investigation, but since their procedures are neatly laid out in advance and the final outcome is already known, they do not really engage students in discovery. At the other end of the spectrum, students attempt to conduct original investigations of their own choosing — come up with an interesting question about natural phenomena, design methods of collecting data to answer that question, analyze the data and provide results. While this other extreme clearly engages students in genuine inquiry, it is a highly challenging form of classroom activity for both teachers and students (Polman, 2000).

The notion of inquiry in LeTUS curriculum design lies in between these two poles. In general, the questions to be explored are set out by the curriculum designers, but the means of exploring them and/or the findings that will result are more open-ended. In addition, LeTUS was concerned with designing inquiry activities that were supported by learning technologies. Thus the topics selected for students to investigate were generally those for which some kind of technology was useful. Using curriculum "seeds" in the form of either specific tools or curricula and activities created earlier, the researchers in each site worked closely with their local districts to build curricula meeting these goals within in the context of the districts' priorities, structure, and needs.

Design teams versus work circles

Teams at the two sites worked more or less separately on curriculum development for two reasons. First, they were working hard to make the curricula they designed fit local needs, which meant working closely with local teachers and schools and learning from the specifics of their particular context. Second, they needed to learn how to develop curriculum. As one researcher put it, “We were not curriculum developers. We are educational researchers and classroom instruction people. It’s not that we never worked with teachers in classrooms, but we never wrote full curriculum. … And so, I think we had to figure out within our own environment how you do that” (Krajcik interview, June 5, 2003).

It is therefore not surprising that the form the work circles took in each site was somewhat different. The general consensus is that “work circles” was a more deliberate approach with the Chicago branch of LeTUS. The Detroit group, on the other hand, used more of a design team approach.[7] In the description of the LeTUS curriculum design processes which follow, more time and attention is paid to the work circle approach used in Chicago. It is a more unusual model for curriculum design and the researchers spent more time tracking that process, making it possible to provide a richer picture.

Design teams and Detroit curricula

The development of curricula by the University of Michigan and Detroit Public Schools is described by them as a “collaboration among teachers, school and district administrators, university scientists, educational researchers and curriculum specialists” (Singer, Marx, Krajcik, Chambers, 2000, p. 166). Joe Krajcik, a science educator by training, led the core curriculum design team. Initially this team consisted of himself, Marx, Singer, Gray and two Detroit teachers with project-based science experience, Barbara Steel and Stella Novak (pseudonym). This group decided upon the topics that each unit would explore and put together an outline or overview for the units.

Gray played a significant role in helping the team select topics the district would find useful. Topics were chosen carefully so that they corresponded with the timeline that Detroit’s standard curriculum dictates for which topics should be taught when. Initially, they built their curriculum by starting with a driving question or general topic that seemed to fit reasonably with the Michigan benchmarks. Then they created a set of activities to support the chosen investigation. At the end of this process, they compared what they had designed to national and local standards. Later, however, they began the design process by looking closely at the district’s curriculum framework and the Michigan Benchmarks and *then* choosing topics to pursue. “That’s one of the changes that was made on the university side. … They were accommodating the needs of the teachers because the first thing a principal asks is, ‘How is this going to help my MEAP scores?’ The first thing a teacher is going to ask is ‘How is this going to prepare my kids for the standardized test?’”(Steel interview, June 4, 2003). The shift made it easier for teachers to justify spending long periods of time on a single investigation. Instead of creating their own lessons based upon the Detroit framework and resources, teachers could use the LeTUS curricula essentially as replacement units and be secure they would be covering the topics the district and state deemed important.

---

[7] *Work circle* is a term developed and defined by the LeTUS participants and all interviewed agreed it has come to be more associated with the Chicago/Northwestern site’s design process. The label *design team* is not one the interviewees employed, but rather one I am using to distinguish the two practices.

Each unit had a point person who was the central designer, usually a graduate student at University of Michigan. The point person would work with the design team and one or two collaborating teachers to build an initial unit framework and sequence. Gray and Steel would then bring in teachers to pilot the ideas and basic activity designs. They chose schools and teachers to participate that they felt had the capacity to engage in this early piloting work. Initially, there was just a handful of pilot teachers (three or four). They were often working with a sketchy framework of inquiry activities, and so needed to be capable of working "with the craziness of it" (Marx interview, June 4, 2003). The following summer, they would tear apart the pilot curriculum and rebuild it. Every summer afterwards they would do some tinkering based upon what they had seen in classrooms or heard back from teachers. Especially in the first couple of years of each unit's life cycle, these revisions could be extensive, which posed a challenge to teachers trying to get comfortable with new material: "This drives teachers insane because there's always new curriculum. It's never what they did last year," (Fishman interview, June 4, 2003). Eventually the district asked the University of Michigan team to stabilize the curriculum so it would not need such frequent revision.

By the end of the Center's grant cycle, the researchers at University of Michigan did most of the writing and revision of the curriculum. They got feedback from the practitioner community through three major conduits. First, they chose some portion of the teachers working with the curriculum to interview at the end of a unit in order to get detailed feedback. These interviews often occurred during the monthly professional development meetings, and discussions within the meeting itself served as another conduit. (Representatives from University of Michigan generally attended the monthly meetings, sometimes simply taking notes, at other times video-taping or interviewing teachers.) Finally, the lead teachers who ran the professional development sessions reviewed the revisions and gave the researchers feedback based on their own experience and their conversations with the other teachers.

The teachers valued the effort the researchers put into revising and improving the curriculum, an activity they didn't feel they had the time to do on their own, "We have our students that we're taking care of, that's our main responsibility" (Detroit teachers focus group, June 15, 2004). As a result, curriculum improvement was one of the reasons they saw the researchers as a necessary part of LeTUS, "I don't think the curriculum would be the same. I don't think it would be updated. I don't think it would be improved upon if they went away" (Detroit teachers focus group, June 15, 2004).

Despite the fact that most of the development work was done by the researchers, the teachers interviewed felt real ownership of the LeTUS curriculum. "Initially, they had the concepts and the ideas of the units," noted one teacher (Detroit teacher leaders focus group, June 15, 2004). Nonetheless, teachers' ideas were an important aspect of the curriculum. "This is more of a collaboration between the teachers and the University. Because of that, I think we have a lot more ownership and we don't hesitate to say, 'Hey look, this doesn't work and we need something else.' They don't hesitate to say, 'Well if you don't think this works, do you have something to offer?'" (Detroit teacher leaders focus group, June 15, 2004). While the curriculum stabilized somewhat, the teachers believed that a certain continued flexibility in response to their needs was important. "It's almost like if it was a stone document, we probably wouldn't use it because the textbook is a stone document. I don't use a textbook. … Those changes reflect our student population and the needs of those particular students," (Detroit teachers focus group, June 15, 2004). As a result, the teachers interviewed seemed to think of the LeTUS curriculum as "our" curriculum rather than "their" [the university's] curriculum and to be sincerely satisfied with its overall design.

Work circles and Chicago curricula

There was no core design team at Northwestern, but rather a loose federation of small groups of researchers and educators working together on curriculum design. In the fall of 1997, the researchers at Northwestern collaborated with the Chicago district personnel in charge of the Chicago Urban Systemic Initiative (CSI) to identify schools to participate in LeTUS. "One of the things CSI had expertise in … was which schools' level of capacity was up to speed for doing the kind of work we wanted to do" (Northwestern researchers focus group, June 18, 2004). Members of the research team met with the principals of those schools to discuss the Center's plans, see if they were willing to participate, and discuss which teachers might be good candidates for becoming involved. Then in the winter of 1998, they held a day-long meeting with all the interested educators in which the researchers described the goals of LeTUS. At the end of this meeting they broke into small groups based upon areas of curriculum interest. Those groups eventually became the work circles.

The initial choice of topics to be explored in the work circles tended to be driven by proto-curriculum already at hand (e.g. from CoVis or BGuILE) and core pieces of software that were available (e.g. World Watcher). Later, there were units developed simply because someone thought it would be a good topic to cover. These units might use off-the-shelf software and/or the technological tools from University of Michigan or Northwestern University.[8]

As at Michigan, each unit had an advocate who was in charge of the work circle doing that design work. The "advocates" for each work circle were usually members of the research team, such as graduate students or post-docs. (There was at least one later work circle run by a teacher.) The advocate generally facilitated the work circle design meetings and collected, tracked, and maintained the design work as it was completed. The units were designed collaboratively, however, the advocates often did the initial "write-up" of the designs. After pilot testing, the teachers frequently took over the task of cleaning up, rewriting and refining them.

The work circle design teams differed greatly in composition. They varied in size from three to sixteen people. Most included both teachers and researchers, though nearly all included more of one than the other, with some teams researcher-heavy and others teacher-heavy. When the work circles began, the Northwestern research team had

[8] In rare cases, work circles were also formed to work on particular problems. For example, the Chicago teacher leaders focus group mentioned that a group of teachers had formed one work circle to create a set of recommendations and adjustments to one of the units to make it accessible to English language learners.

graduate students taking notes about the working processes themselves. This data collection showed that the specific working relationships within each team differed based upon the facilitator running them, the curriculum seed they were working with, and the experience and background of the teachers involved (phone conversation with participating graduate student, December 15, 2004). Universally, there were some tensions around researcher and teacher definitions of the structure of curriculum. And several groups struggled initially to create a working relationship in which all members of the work circle felt equally valued. Each group handled these tensions in different ways, but nearly all came to have a productive working relationship (phone conversation with participating graduate student, Dec. 15, 2004).

Below, the work of the *Realizing New Urban Environments* (ReNUE) work circle is used to illustrate how one team of teachers and researchers designed collaboratively.[9] The overall procedure they used for working on the curriculum is described. This description is followed by a review of some of the major design questions they faced as a group and the way in which each was resolved. Collectively, the design procedures and design questions demonstrate a complex interaction of knowledge and expertise within the group. Both teachers and researchers brought critical knowledge to the task and each had to make changes in the way they thought about curriculum as they worked. Most important, not all their final decisions were compromises. Depending upon the issue at hand, sometimes the teachers' perspective was the most important one, and sometimes the researchers' was. Establishing a working routine and mode of communication that enabled these perspectives to be surfaced and decided between was thus critical in their work.

The ReNUE work circle

The ReNUE work circle began its efforts in January of 1998 (Shrader et al., 1999; Shrader, et al., in review). The team consisted of two Northwestern researchers, four science teachers and one school technical coordinator.[10] The curriculum seed they chose to use was a CoVis Interschool Activity (CIA) in which students create a land use management plan or LUMP. The CIA was an adaptation of a project cycle used by one of the original six CoVis teachers (D'Amico, 1999). She used it in her environmental science class as a way to help students understand the complexity of environmental concerns and to grapple with the idea of trade-offs between environmental health and community needs and desires. The core idea behind LUMP was a simple one:

> Students will develop a land use management plan for a specific area. First, they must define the existing environmental problems of their area. Then, they must propose a plan to solve them. Students should be creative and logical in developing their strategy. Plans must be workable for the designated area. Hence, students must provide evidence which demonstrates the feasibility of their proposal (CoVis Geosciences website, www.covis.northwestern.edu).

---

[9] This work circle was chosen because it is a well-documented one and three of its participants, Greg Shrader (researcher), Lou-Ellen Finn (teacher-cum-professional developer), and Judy LaChance-Whitcomb (teacher) were interviewed for this study either individually or as part of a focus group.

[10] Interestingly, the team included teachers who did not have students for whom the unit they were designing was targeted. They nonetheless participated fully in the design work.

One of the team members, Judy LaChance-Whitcomb, had been a CoVis teacher and used LUMP in her classroom. Just one month before the ReNUE work circle began, Greg Shrader, a researcher on the work circle, had done a case study of LUMP in LaChance-Whitcomb's class as part of his dissertation research (Shrader & Gomez, 1999). LaChance-Whitcomb's deep experience with the curriculum seed would prove quite useful to the work circle and enabled its members to pilot their work before most of the other teams. "Judy knew a lot more about doing project-based science than some of the other people. So we really had an advantage over some of the other groups who were really starting from a much more beginning place" (Finn interview, June 6, 2003). Others in the group had different kinds of expertise to lend to the design process, including a teacher with knowledge of district policy and resources related to educational technology and others with expertise in literacy, district and state standards, and school and district curriculum initiatives. The two researchers brought expertise and knowledge related to cognition and learning, the integration of technology into learning environments, educational policy, and the design of project-based science units. All of this expertise became useful at some point in their work. (Shrader et al., in review, p.41).

In addition, Shrader's insights on LUMP through his earlier research proved useful to some of their design discussions. However, the group members did not start their work with those insights. Instead, they began their work from the teachers' frame of reference. As Table 1 shows, the ReNUE design process had four stages: Mapping the project to standards, creating a project overview or outline, designing activities and piloting the curriculum (Shrader et al., in review). The first of these stages relied largely on the teachers' expertise. "From that very first meeting, instead of saying, 'Here's what we want to do,' it was, 'If we're going to develop a middle school science curriculum, what are the things that you as teachers have to have?' So we started talking about standards and that sort of thing" (Finn interview, June 6, 2003). Because the *Chicago Academic Standards and Frameworks* were currently very important to the teachers, the work circle decided to start by examining them in relation to the curriculum seed they had chosen. At this point in time they were meeting after school every other week for two or three hours in one of the participating teachers' schools. For these first couple of weeks, the teachers were the experts — they knew the *Chicago Standards and Frameworks*, and LaChance-Whitcomb had significant experience with the LUMP project — so they drove the conversation.

After a thorough examination of the relationship between the curriculum seed and the standards, the teachers felt they were ready to begin drafting an overview of the unit — a basic frame to support their design work that would outline the inquiry goals and the activities for meeting those goals. (See Appendix C.) It was at this stage that the researchers' opinions and knowledge started to become a stronger part of the conversation.

Table 1: Phases of design in the ReNUE Work Circle (adapted with permission from Shrader et al., in review)

Design Task	Description	Design Issues
Case study of LUMP (One month before ReNUE work circle began)	• Case study of former CoVis teacher implementing LUMP, the curriculum seed for ReNUE	• Researcher identifies two problem areas: (1) Student research skills — trouble finding and interpreting information sources on environmental problems (2) Limits of a physical modeling task for engaging students with scientific concepts
Standards Map (First 2 weeks)	• Participants examine the *Chicago Academic Standards and Frameworks* to determine what standards might be addressed by the ReNUE project. Those standards were subsequently used to guide design. • The initial project seed (a project from CoVis) is studied closely in relation to these standards. • Meet every other week in one of the two schools where the participating teachers work.	• The teachers are the experts on the *Standards and Frameworks* documents • The project seed has been used by one of the participating teachers in the past; her expertise is drawn upon heavily
Project overview	• Participants write a project overview that describes the project in terms of students' inquiry goals and the tasks through which those goals will be pursued. • Project is outlined as having four phases.	• Researchers bring in their beliefs about the essential elements of a "science project" • Researchers argue for design rationale and teachers argue against it • Collectively decide to use case studies to support student research • Collectively decide to build conceptual, rather than physical models
Writing activities (2 months)	• Drawing on the standards map and the project overview for guidance, lesson plans are written that describe the project at the level of day-to-day work. • Participants work on their lesson plans individually at home. • The group is now meeting weekly and each meeting focuses on discussing and editing the design work done individually.	• Detailed discussions of modeling activities o Researchers advocate use of Model-It o Teachers wary of learning overhead for both modeling and software
User testing	• One teacher implements the ReNUE project in her classroom and reports the results to the work circle. • Only two phases of the project complete at the time the user testing begins; increases urgency around design activities. • The results are used to redesign the completed activities and to inform those yet to be designed.	• Refinement of supports for student research—Teachers suggest worksheets to scaffold reading comprehension • Teacher testing of the use of Model-It—finds it valuable

After the project overview was agreed upon, the work circle began writing specific lessons and activities. During this stage, each member of the team worked on creating lesson plans that described the day-to-day activities for the project. Activities were divided up among the work circle team members. Participants would work on their lesson plans at home, using as guides the standards map, the project overview, and a set of design principles for project-based science the group had agreed upon during the overview stage. Their designs would then be brought back to the work circle for discussion and editing. As they got closer to the user testing stage, they increased the pace of their meetings to once a week.

In March of 1998, with the first two phases of the curriculum complete, Finn began user testing ReNUE. This piloting activity required a certain amount of both bravery and flexibility on Finn's part. When asked how the piloting went, Finn said, "It was a fly by the seat of your pants kind of thing. … All things considered, it wasn't bad. (laughter) I mean there were literally days when Greg [Shrader] would show up at my classroom door with stuff that he had printed out up here [the Northwestern campus] that morning. ... And so it was sometimes a challenge" (Finn interview, June 6, 2003). Thus, as in Detroit, those teachers who initially tried out the fledgling curriculum ideas, had to be capable of dealing with "the craziness of it all."

What Finn learned and experienced from trying those activities out was fed into the design of the rest of the unit, as well as plans for redesigning each activity already tried. At the same time, Shrader was video-taping all this early piloting work for both research data and feedback into the design. Based on the pilot data, the group worked over the summer to revise the unit and then it was piloted with other teachers that fall. The work of most of these teachers was not observed,[11] but the students were given pre- and posttests and a focus group was run with the teachers in January. Then the teachers involved in the work circle redid the curriculum one more time. In the end, their final unit looked very little like the CoVis seed project from which it began.

In the course of the ReNUE group's work, four design questions emerged that would become major loci of conversation and negotiation within the group: (1) What is a project? (2) How important is it to include design rationale within the curriculum? (3) What is the best role for modeling within the curriculum? and (4) What is the best way to support students' efforts to conduct research on environmental problems? (Shrader, et al., in review). Both the origin and resolution of each of these questions differed. Comparisons between them demonstrate ways in which teacher and researcher knowledge and expertise interacted within the work circle. While compromise was one strategy, it was not the only one. Sometimes the teachers' perspective prevailed, sometimes the researchers did, sometimes both changed their minds, and sometimes they crafted a solution that allowed them to agree to disagree.[12]

---

[11] Many graduate students were graduating and the project was short of people to be in classrooms. Finn's classroom was an exception as it was being filmed for use in the Living Curriculum Project.
[12] The following discussion of these four questions draws heavily upon Shrader, et al., in review. However, they are clearly strong markers in the group's collective understanding of their work as reference to them surfaced in interviews with Shrader, Finn, and a focus group that included LaChance-Whitcomb.

Two of the questions – the role of modeling and the best way to support student research – initially emerged as issues during Shrader's case study of LaChance-Whitcomb's classroom. In his study, Shrader noticed that students were having difficulty identifying the environmental problems of their area and then finding information about those problems. He also concluded that the physical models students were producing to illustrate these problems and/or their solutions were not engaging students deeply in the scientific concepts underlying them. Both these concerns were shared with the team during the project overview stage of the work circle.

The group decided to solve the research problem by giving students specific environmental problems to explore and choosing cities emblematic of these problems. This "case" approach meant that students no longer needed to identify the environmental problems of their area and the design team could put together a base set of resources on each problem/city to get the students started on their research. Students could then apply what they had learned about the case to similar local environmental problems. After exploring a number of options, this solution was readily agreed upon by the entire team and it was not revisited until the user testing stage of the work.

During her pilot work, Finn noticed that a number of her students were having difficulty reading and interpreting the information sources available them. She concluded that they were skimming the resources looking for key phrases and when they did not see them, dismissed texts that actually provided the information they needed. Another teacher in the work circle suggested the development of a worksheet that asked students to look for the causes and effects of their problem during their reading. This idea was then turned into that of a journal for recording causes and effects. Its use in the classroom had the intended effect of improving students' capacity for reading and interpreting the texts available to them. This incident, along with similar ones in other LeTUS classrooms, led one of the LeTUS researchers to begin a program of research exploring the link between literacy skills and students' learning in LeTUS classrooms.

The question on modeling was resolved differently. During the overview stage, everyone agreed that conceptual models would need to replace physical ones. However, when the researchers suggested the use of Model-It, software for dynamic modeling created by the hi-ce group at University of Michigan (Jackson, Stratford, Krajcik & Soloway, 1994), the teachers had two major concerns. First, they were concerned that the software would be difficult for teachers to learn and therefore they would feel insecure about their ability to support students' use of it. Second, they worried that teaching students how to model a system while simultaneously teaching them the software would be too complicated a task.

The group wrestled with this problem for some time. In the end, they decided to break the task down. First, they would teach students the language and methods of conceptual modeling by creating paper-and-pencil models. After this stage was complete, students would learn to use Model-It and transfer their models to the software. Finally, both these tasks were broken down into mini-lessons each addressing a key concept needed to use Model-It. These mini-lessons were supported by a teacher demonstration example included in the curriculum materials. The mini-lessons and demonstration example were designed to support teachers' efforts to introduce modeling and Model-It.

The participants note that this solution was strongly guided by teacher suggestions and needs. They believe that the researchers on their own would have been more likely to take a holistic approach rather than breaking the task down in this fashion (Shrader et al., in review, p. 27). Indeed, not all the teachers were satisfied even with this solution. Some argued that low-tech paper-and-pencil modeling was sufficient – it took less time, required fewer resources and was less complicated to support. The researchers argued that the built-in scaffolding and dynamic response of Model-It would support deeper student reflection on their models. In the end, the group decided to let the results from the user testing inform their decision. Finn was convinced after doing the pilot that Model-It was worth the effort. Other teachers in the group, however, were not. The structure of the final design supports both perspectives. Teachers may do both forms of modeling or simply the paper-and-pencil piece.

The modeling question began with a group agreement about the problem at hand, but some conflict over the best method of solution, with teachers and researchers bringing different perspectives to bear. In contrast, the "What is a project?" question surfaced when researchers realized they and some of the teachers did not have a shared understanding of the nature of project science. As they were outlining the unit during the overview stage, the researchers noticed that some of the teachers in the group saw a project as essentially a group of activities organized together and related to a common theme. The researchers had a different conception. To them "a project was a student-driven inquiry organized by a driving question with tasks and activities constructed to constitute an investigation of that question" (Shrader et al., in review, p. 17).

Rich Halverson, Shrader's fellow researcher on the team, argued that they should tell the teachers in their group what they thought a project was. Shrader worried that this would not be participatory, but Halverson convinced him to do it. Together they wrote up a one page description and brought it to the next meeting. To Shrader's surprise, the teachers appreciated it. They spent the rest of the meeting fleshing out their collective understanding of what a project was and then creating a set of design principles for project-based science. These principles became a reference point for their future discussions. (Shrader et al., in review).

> I learned a lot from that. I learned that we [the researchers] do know something and just because we're trying to build capacity doesn't mean we should forget what we know. A lot of times at the beginning of a work circle, the teachers would want to defer to what they thought was the expertise. That's why I was sensitive to them in the first place. You had to almost train them and you had to train yourself to know when it was one of these things that we were really going to care about and without it, it doesn't respect the larger intent. And, when is it that I just want it this way because I think it's important and I'm not hearing what they're telling me about why it won't work (Shrader interview, June 6, 2003).

The final major design question, "How important is it to include design rationale within the curriculum?" also surfaced during the overview stage of their work. It did not, however, have as simple a solution. In fact, it was a raging argument between the teachers and researchers that spanned the entire course of their design work together. This dispute is also, perhaps, the best piece of evidence that the group had created a productive and respectful collaboration. They recall taking strident positions and being exasperated, but they also laugh as they tell the tale and in the end, both sides changed their minds.

The dispute began with a researcher concern about lethal mutations. All teachers adapt curricula to suit their needs and that of their students. This is as it should be. But researchers have long known that some adaptations are misappropriations that disable or defeat the purpose of curricula or innovations (Brown & Campione, 1996). The researchers on the ReNUE work circle suggested including design rationale that would explain the purpose of the curriculum and the reasoning behind its design. They then hoped that this design rationale would inform teachers' adaptation and implementation of the curriculum in a way that would avoid lethal mutations. The teachers argued that no teacher in their right mind would bother to read a design rationale, so its inclusion was simply wasted ink. "I fought that tooth and nail because Greg [Shrader] wanted design rationales put in every lesson. … I went kicking and screaming, saying, 'Never. Over my dead body'" (Finn, Chicago teacher leader focus group, June 16' 2004). In the end, the team compromised, agreeing to write design rationales for each lesson, but to include them in an appendix at the end of the unit and continued to debate the whole issue as they worked.

It was not until the curriculum was ready to be shared with other teachers that either teachers or researchers began to reconsider their positions. The teachers found that having written the design rationale, they were well prepared to answer the questions of new teachers looking at the curriculum. And, as Finn noted

> At the end … I finally went back and said, "We need to do that," because as a teacher, more than once when I was going through a textbook, I'd go, "Why am I doing this now? I'm not going to do that." And then I'd get four lessons down and I'd go, "Oh crap, I should have done that because there was a reason for doing it even though it wasn't apparent to me." So, if we can make that apparent to a teacher … that's really important (Chicago teacher leaders focus group, June 16, 2004).

On the other hand, the researchers became convinced that the teachers' original perspective was correct. Experience showed that new teachers "were rarely interested in the theoretical discussions of design rationale and did not use the design rationale to inform their own teaching" (Shrader et al., in review, p. 20). Interestingly, the researchers also found that teachers did read and attempt to understand examples of student work used to illustrate the design rationale (Shrader, 2000).

Thus the act of *writing* design rationale was useful to the curriculum creators in that it forced them to explicitly articulate their design reasoning in ways they could later use when talking to others. But the rationales themselves were not useful unless attached to concrete examples. Most important, the discovery of these findings did not take place until the work circle members stepped out of their work and presented it to others.

Together, these four design questions or debates demonstrate the mix of knowledge and expertise researchers and teachers brought to bear in the ReNUE work circle. The researchers brought a broad design perspective, knowledge from the field on relevant design issues (e.g. lethal mutations and the nature of projects), and research data and experience from classrooms doing inquiry work (e.g. Shrader's case studies). The teachers brought an understanding of their district context, but also on-the-ground experience of what teachers and students can and will do that informed the pacing and structure of their designs. While each work circle team functioned differently, this broad characterization is somewhat consistent. "What we learned as we went along was that teachers were not prepared to think about design in the large in lots of cases. That what they really wanted to focus on was individual activities, individual labs … so it was a lot that turned out very often to be kind of local, very specific contributions" (Northwestern researchers focus group, June 18, 2004).

These local contributions, however, were highly valued and teachers describe the experience as being an empowering one. Finn noted that she really did *not* feel like she was following a researcher's pre-planned agenda, but rather that her expertise was truly valued:

> I've been teaching a long time, over 30 years, when I got involved with them, and so it is not the first time I've been involved with researchers. And my previous experiences with people who wanted to do research or wanted teachers to use a curriculum or a piece of curriculum had never been really positive. I mean, it was never horribly negative, but I always felt like it was — we're going to come in; we're going to use you and your kids and we'll walk out the door and that's the last time we ever see you. And you never heard anything about what they found out about what you were using or any report on their research. It was just like this stop along the way and they needed you but they really didn't want you to be part of it. So at first I was somewhat skeptical of getting involved with these guys. (Finn interview, June 6, 2003).

Her involvement in LeTUS was quite different. "Clearly from the beginning, we were a part of what was happening. None of us ever felt that this was their agenda and we had to fit into their agenda. And Judy and I talked about this many times, the fact that we always felt like we were heard" (Finn interview, June 6, 2003). When during the summer of 1998, Finn and several other teachers spent some time doing curriculum design work at Northwestern, she was impressed by the accessibility and friendliness of the senior researchers on the project. "People around here don't make those distinctions in rank. And they're there. I mean, how could they not be? But it's not apparent and everybody's office door was always open and if you had a question and Louis [Gomez] was in his office you could go in. That was, again, it just added to that whole feeling of everybody being part of the same group," (Finn interview, June 6, 2003).

Finally, all those involved in ReNUE believed it to have been a worthwhile learning experience. All learned more about the science content involved in the unit. For example, developing materials on air pollution led to the group learning about thermal inversion (Shrader et al., in review, p. 33). Researchers had the opportunity to test their broad design ideas against teacher and classroom realities and have them tempered and refined by practice (Shrader et al., in review, p. 32). Likewise, the teachers saw their participation in the work circles as being some of the deepest professional development experience of their careers. Finn explains that designing curriculum provided a regular, structured time and place for deeply reflecting on practice. "Things we wouldn't have thought about before, or maybe thought at some buried level, … got pushed to the front. How much do I really know about where my kids are? Do I really take time to think about what they're bringing into the classroom and what their prior knowledge is? What do I do with the kids who are going off and all of that? … To provide teachers with that opportunity is huge" (Finn interview, June 6, 2003).

The resulting curricula and their effectiveness

The curricula that resulted from this design work differed somewhat between the two locations and even within each location. (See Appendix C.) However, a rough contrast can be drawn between the two sites. The Chicago curricula tended to be structured around a core open-ended project or investigation. For example, in ReNUE, students were asked to study interesting cases of environmental problems in cities world-wide, build a model demonstrating the problem, propose a scientifically justifiable solution, and discuss how what they had learned might be applicable to a similar problem in their own city. Each project or investigation is then front-ended with introductory activities and materials that supply background information, necessary concepts, basic skills, and motivation for conducting that investigation. For example, in ReNUE there were lessons aimed at getting students interested in the issues of pollution and environmental health, others focused on introducing key terms and concepts related to the study of environment, and others aimed at developing internet research or group work skills. The Chicago/Northwestern team was concerned about teachers' time and so the written format of the lessons tended to be text-lean, with much use of terse bullet points that can be skimmed quickly.

The Detroit curricula are structured more like "units". There is a driving question, broken down into related sub-questions that get at core concepts related to the driving question. For example, in the communicable disease unit, the driving question is, "How can good friends make me sick?" This question is then broken down into others, "Is anyone sick?" (introduces the driving question and the nature of disease), "What makes me sick?" (explores the causes of disease), "Why do diseases spread?" (explores both the spread of and resistance to disease), and "What happens to me when I get sick? (explores the effect of disease on body cells and the immunological response to disease). The activities and materials in each sub-section include inquiry activities, traditional labs, readings, discussions, etc. Interwoven through the activities of the communicable disease unit is a "disease investigation" in which groups of students study particular diseases as they learn about disease in general. The written format tends to be text-rich with lots of detail and supportive commentary.

The LeTUS curricula and associated software generated by these teams of teachers and researchers were not often used across sites. This lack of transfer is at least in part because the curricula were tailored to the standards, guidelines, or frameworks for each district and thus did not often fit well in the other district. The differences in curriculum format may have also played a role. The Detroit teachers found the reading level of the

Chicago curriculum to be too challenging for their students and the Chicago teachers found the Detroit curriculum to be a bit too text-rich for easy use.

There were some tools that transferred. Model-It, a software program for dynamic modeling created at the University of Michigan, was used in some of the Chicago curriculum development. It is a general-purpose tool for modeling that could be applied to students' inquiry work in a variety of domains. Its flexibility with respect to content may have facilitated its use across sites. Likewise, the Chicago site was able to use the Water Quality unit devised by the Detroit/University of Michigan team as one of its offerings. The decentralized nature of science curriculum in the Chicago Public Schools may have been part of the reason. Since there was no centralized curriculum adoption nor guidelines for order and pacing of topics, Chicago teachers could use the units as they and their schools chose. Thus, while the Chicago curriculum development teams listed a suggested grade level for each unit (see Appendix B), Chicago teachers used them for a variety of students, including students in the upper elementary grades (grades 4 and 5).

Impact on student learning

The LeTUS researchers note that they have collected impressive examples of student work done within the context of LeTUS classrooms that show urban students can engage in reasoning and produce work as accomplished as that of students in more privileged settings, or indeed, in any setting (Gomez interview, June 6, 2003). They have also demonstrated improvements in learning via both pre- and posttests as well as on politically critical city and state tests of science achievement.

Pre- and posttests designed by research staff to go along with the curriculum units show learning gains. The hi-ce group had begun developing such assessments fairly early, at least in part because a grant they received aimed explicitly at developing assessments of student learning. The paper-and-pencil assessments they created consisted of both multiple-choice and free response items. Some of these items were designed to capture students' *curriculum content knowledge*, while others assessed their *science process skills*. The content and process items were futher categorized as belonging to one of three cognitive levels: *lower* (e.g. recalling information), *middle* (e.g. shifting between representations such as verbal and graphical) and *higher* (e.g., defining or isolating variables in a given scenario).

In a recent paper (Marx et al., 2004) LeTUS researchers at University of Michigan review findings from the pre- and posttest data collected for five different units over three years (from 1998-99 to 2000-2001). These data show statistically reliable gains in both content and process skills and across all three cognitive levels for all five curricular units in all three years.[13] Furthermore, the effect sizes of these gains were more robust in 1999-2000 and 2000-2001 than they were in 1998-99.

---

[13] Exceptions are: the process score for the 1998-99 administration of the Water Quality unit; the "low" items for the 1998-99 Air Quality unit and the "high" items on the 1998-99 Water Quality unit. Also, the gains on content items were more robust than those on the process items.

Because of mutually agreed upon procedures established with Detroit Public Schools, the hi-ce team does not collect, nor do they report data based upon the racial or ethnic identities of students. The research team at Northwestern, however, has been able to compare pre- and posttest differences in achievement between boys and girls, black and white students, and those from impoverished versus more affluent backgrounds. The development of pre- and posttests at Northwestern did not begin in earnest until a couple of years into the Center's work. As a result, their data do not go back quite as many years and they are still in the process of completing some of their analyses. Thus far, their work shows gains between the pre- and posttests overall as well as gains for both impoverished students and those from middle-class or affluent backgrounds (Herman, Mackenzie, Sherin & Reiser, 2002; Herman, Mackenzie & Rose, 2003; Herman, Mackenzie, Reiser & Sherin, 2003).

Herman and Marx, who coordinated the pre- and posttest development in Chicago and Detroit respectively, both shared methodological concerns about their findings from these data. Marx pointed out that the pre- and posttests are designed specifically to assess what the units are meant to teach, "So in a sense, it's not surprising that we're able to get decent effect sizes" (Marx interview, June 4, 2003). He noted that the districts might find such data somewhat self-serving and were much more concerned with the results of the politically important tests required by the state.

Herman pointed out that it is difficult to interpret the pre- and posttest data without knowing something about how each teacher enacted the curriculum. He explained that the Northwestern team works hard to get the results of the pre- and posttests back to teachers quickly — a difficult task considering the labor involved in scoring the open-response items on the tests — and discussing those scores with them. During those discussions, the teachers often talked about how they think the choices they made in enacting the curriculum may relate to the scores their students received. Herman said it was not uncommon for the teachers to look at the tests and how they were scored and say something to the effect of, "Oh, I didn't know that this is what the curriculum was about!" (Herman phone conversation, September 16, 2003). Since the pre- and posttests only *sample* the content and processes students are to learn, there was some concern about the effect the test results would have on how the teachers enacted the curriculum in the following year. Would it be a positive one? Or would it somehow constrain their vision of what the curriculum is about in unfortunate ways?

Teachers in Detroit also got feedback on their students' test results. These were given in the form of scores on the content knowledge and process skill scales. Many of the teachers also scored their students' pre- and posttest for their own purposes. For example, some graded the posttest and then included that score as part of their classroom evaluations for that student's grade. Others gave students extra-credit points for each item answered correctly as a way to encourage them to take the tests seriously. Thus the teachers had the time and opportunity to evaluate their own students' responses to the pre- and posttests. They even cite their students' responses to the posttests as one of the indicators they had that the curriculum was working. One teacher explained that on the last day of class for the year, she had some kids taking a posttest and, "They were going through it and saying 'This is easy!' … When I was reviewing their posttest, they did fabulous. They did great. They learned a lot" (Detroit teachers focus group, June 15, 2004).

In addition to findings based upon pre- and posttest data, the LeTUS researchers also explored the effects of the curriculum on student learning as measured by standardized tests. The hi-ce team at University of Michigan looked at the impact of participating in LeTUS units on student achievement on the Michigan Educational Assessment Program (MEAP) in science in both 2000 and 2001. The MEAP in science provides scores on three science content areas (Life, Physical, and Earth) as well as two science process skills ("Constructing" and "Reflecting"). These scores are combined to create an overall score as well as three proficiency levels ("proficient", "novice" and "not yet novice").

Middle school aged students are tested in science in eighth grade and may have participated in up to three LeTUS units (two available in seventh grade and one available in eighth grade). The hi-ce researchers compared students who had completed at least *one* LeTUS unit during seventh and eighth grade with the rest of the eighth grade students taking the eighth grade MEAP in 2000 and 2001 (Geier et al., 2004). The "non-LeTUS" students included those who may have been in LeTUS classrooms for part of their instruction, but for whom no "end of unit" data (posttest or student survey) was collected, as well as students involved in other science improvement efforts as part of Detroit's Urban Systemic Initiative.[14]

The findings were quite positive. The total scores of students in Detroit classrooms where at least one LeTUS unit was run (n=760) were 14% better than those of the other middle school students throughout the Detroit Public Schools (effect size = 0.44 standard deviations, $p < 0.001$) in 2000. In the 2000-2001 school year, the LeTUS project scaled significantly in the Detroit Public schools, taking on more schools and teachers and concurrently providing less direct support. Nonetheless, the 2001 MEAP scores still showed a strong effect, with the LeTUS students still performing 13% better than non-LeTUS students (effect size = 0.37 standard deviations, $p < 0.001$). LeTUS students also passed the MEAP (achieved "proficient" or "novice" status) at greater rates than non-LeTUS students, with a difference of 19% in passing rates between LeTUS and non-LeTUS students in 2000 and 14% in 2001. Finally, the hi-ce group found that participation in LeTUS was closing a gender gap in which girls typically outperform boys on the MEAP scores in science. In 2001, there was only a 1% difference in passing rate between LeTUS girls and boys, compared to a 9% difference in passing rate between non-LeTUS girls and boys (Geier et al., 2004).

Generally, not every classroom in a school was using the LeTUS units and some schools had no middle school classrooms in which the LeTUS curriculum was used. To make certain that the differences in achievement were due to the LeTUS curriculum and not other contextual factors associated with particular schools, the researchers also reviewed a subset of the data which included only those schools in which at least one

[14] There were at least six other science improvement efforts going on in the Detroit Public Schools that the LeTUS researchers were aware of (Geier, et al., 2004).

classroom was using the LeTUS curriculum. In 2000, these data showed that students in classrooms in which at least one LeTUS unit was used performed 15.5% better on the 8th grade MEAP in science than other students in the same schools (effect size = 0.45, $p < 0.001$). The effect was somewhat smaller in 2001 yet still substantive, with LeTUS students doing 10.8% better than their counterparts in the same school (effect size = 0.31, $p < 0.001$). This change may be related in part to the larger number of participating schools, some of which were higher performers in general (LeTUS Team, University of Michigan, 2003).

Standardized test data in science for Chicago students has been more difficult to access and conclusive findings are not yet available. They did explore to some extent students' performance on literacy tests and saw some indication that the LeTUS units are having a positive effect.

Impact on student engagement and motivation

Marx explained that generally students' academic motivation drops across the middle school years. In Detoit's LeTUS classrooms, the hi-ce researchers are not seeing this drop. While motivation "is not necessarily going up, it isn't going down," (Marx interview, June 4, 2003). They have worked on path models to enable them to look at students' perception of their instructional environment, motivation and science achievement (Middleton, Blumenfeld & Marx, 2003). The story these models told was a rather complex one and did not indicate much of direct relationship between student's motivation levels and academic achievement in LeTUS classrooms. Marx noted that this is a common finding within the field of motivation and achievement.

Likewise, Herman described Northwestern's findings on the links between student motivation and achievement in Chicago LeTUS classrooms as complex. They could explain some of the variance in achievement via motivation, but there are a number of constructs one can use to capture different aspects of motivation. Whether the Northwestern researchers saw effects or not depended upon which constructs were being examined and in which classroom contexts. He noted that in some LeTUS classrooms they still saw the drop in motivation that middle school children typically exhibit. In others they did not. The Northwestern team continued to be interested in untangling what kinds of LeTUS enactment or classroom circumstances lead to a lack of drop (or a rise) in motivation and which of the motivational constructions go up or down.

The research on the effects of LeTUS on students' motivation may have been murky. The teachers' impressions of it, however, were not. They were nearly unanimous in their belief that the LeTUS units are far more engaging to students than other forms of science instruction they have used. "The content is terrific. The materials are engaging. The kids love what they're doing. It keeps me going" (Chicago teachers focus group, June 18, 2004). They described students other than their own crowding into their classes to see what was going on. "Kids who are not in the LeTUS program always want to be in the LeTUS program" (Detroit teachers focus group, June 15, 2004). They cited examples of their own students hanging around on the last day of class to work with stream tables. And they had many requests from students in the years below them to be in their classes.

"They see the quality of the learning that's going forth in the classroom and they respect that. I think the students honor that" (Detroit teachers focus group, June 15, 2004). They also believed the LeTUS experience was having a lasting impression on their students. "I am now beginning to see college-bound students that initially saw these units [some years ago] and they come and see me once in a while and they remember every single thing that happened. So there is something magical happening and we must recognize it" (Chicago teacher leaders focus group, June 16, 2004).

Challenges of implementing the curricula

As much as the teachers interviewed applauded the LeTUS curricula, they did find the units challenging to implement. In general they claimed that it takes about three iterations of a unit before a teacher would feel like she had reasonable mastery of it. The units are long and take considerable class time, especially the first time or two a teacher tries them out. The teachers note that the second unit they attempted tended to be a little easier than the first because the basic framework and some of the classroom practices were familiar. However, simply becoming familiar with a new unit was a large task. The reading required, especially in the Detroit LeTUS units, "is a huge burden. Not only do you read the center of it, you've got to read all the stuff in the margins and all the stuff in the margins tells you totally different ways of teaching than you've ever thought of doing in your life" (Detroit teacher leaders focus group, June 15, 2004). This problem was particularly acute for those teachers who "loop" with their students — staying with the same group of students through two or three grades. Such teachers might only revisit a particular LeTUS unit every two or three years.

The classroom activity during LeTUS units was very different from that of more traditional science instruction and required changes in both teachers' and students' perspectives. Teachers needed to shift from being a "sage on the stage and monitor of children sitting in their seats writing answers to questions, to more of a facilitator or helper. But that can only happen if you can manage to motivate your children to be a student, someone inquiring and looking for answers" (Novak, Detroit teacher leader focus group, June 15, 2004). That process was complicated when there were many classroom interruptions. It takes time for the teachers to get adjusted to their new role, and they found they had to educate both students and parents on what to expect. Those teachers who had students from classes that did LeTUS units in the previous year noticed a definite difference. "The kids came in and they knew the process and so things went a lot smoother" (Detroit teachers focus group, June 15, 2004).

Guiding this activity required much more planning than regular classroom teaching. In addition to becoming familiar with the materials, teachers needed to think about supplies and how best to group their students. But most important, they found they needed time to think about and understand the concepts in the curricula. "Where are you going with this? How does it relate to benchmarks? All of that. You have to kind of look at the whole picture when you're doing LeTUS" (Detroit teachers focus group, June 15, 2004). The LeTUS units push both teachers and students to grapple with natural phenomena and scientific concepts in deep ways. The teachers noted that this requires a great deal of background knowledge on their part in order for them to implement a unit successfully. "You can't just go in and say, 'Okay, we're going to do this page and this page and answer these questions.' With this, you need to know the background. You need to be more prepared." (Detroit teacher leader focus group, June 15, 2004). Moreover, the concepts covered in a unit are interlocking ones:

> Teachers are used to teaching finite topics. I've got this one topic, I'm teaching this. I'm done with it. Then tomorrow I've got another topic. I'm done with that. … Whereas in LeTUS, because the ideas are building on each other, you're not done with it. It really is supposed to help you understand something else. But for kids, they don't see the connections unless you as the teacher really point them out (Detroit teacher leader focus group, June 15, 2004).

Most teachers were so busy "surviving" the curriculum the first time through that they were not able to help students make these subtle connections. That work began the second or third time they used each unit (Detroit teacher leader focus group, June 15, 2004).

The curriculum also required concentration during class. A number of teachers complained that high levels of interruptions were a continual source of frustration.

> I don't care how good your [school] administration is, they still don't understand. You cannot have fifteen interruptions when you're doing projects. I don't care if it's the PA or the door opening. … I think after a point my kids were ready to shoot. … "Ms. X, go lock your door so no one can come into the room." We pull the shades. I mean, even my curriculum leader does not seem to understand, "You can't come in." … So, next year, I'm putting a sign on my door, "Project-based. Leave us alone" (Detroit teachers focus group, June 15, 2004).

There were a number of other challenges mentioned by the teachers. Early versions of the curricula did not have enough assessment opportunities built in along the way to gauge student understanding (Detroit teacher leader focus group, June 15, 2004). The Chicago teachers had trouble using the materials with English language learners (Chicago teacher leaders focus group, June 16, 2004) and found the curriculum had gaps due to some of the prior knowledge required for doing the units (Chicago teacher leaders focus group, June 16, 2004). All the teachers complained that it was difficult to get regular access to enough viable computers to use the technologies associated with the units. One teacher described printing out computer screens and having her students fill them out with paper and pencil because the lab was always booked or the machines down (Chicago teacher leader focus group, June 16, 2004). And finally, the Detroit teachers commented that reproduction of the materials (photocopying) was a constant problem. The Detroit LeTUS curriculum came with a reader for students as well as activity sheets, etc., and they were constantly running into either technical or financial problems associated with copying these.

Some of these problems (e.g. lack of sufficient assessments) were ones to be addressed through further curriculum redesign. Others (e.g. interruptions) are problems that need to be solved by the school community. Still others (e.g. the reproduction of materials) may have implications for how the district structures its resources. But many were best handled through the provision of high quality professional development.

WORKING TOWARD SCALE AND SUSTAINABILITY: PROFESSIONAL DEVELOPMENT

Once the curriculum had been developed, the collaborators needed to recruit teachers to use it and to provide them with the support necessary to implement it. It became increasingly clear as the work progressed that the need for a strong professional development infrastructure was critical. One central component of that infrastructure was the hiring of a LeTUS liaison in each district.

Each liaison was a former science teacher hired (using the district's LeTUS funds) to serve as a LeTUS curriculum specialist within the district and a bridge to the university community. Barbara Steel (Detroit) and Chandra James (Chicago) worked in the district administration in offices related to the provision and oversight of science instruction throughout their systems. They played critical roles in coordinating the professional development offerings in each district. They provided one-on-one assistance to individual teachers. They coordinated with the university personnel about both the development and provision of courses, workshops, on-line support and other means of professional development related to LeTUS. Known and respected by both the school leadership and the teaching force in science, they helped recruit teachers and schools and served as liaisons between teachers, district administrators, and the research teams.

When "control" classrooms were needed, they located them and provided the initial contacts. I was fortunate to hear Steel negotiating with one such school about participation as a control. She did a better job than most university researchers at explaining the essential focus of the study and the role she was asking them to play. She had a clear and deep understanding of the wide range of grants, research projects, and questions being explored under the LeTUS umbrella. She also had strong relationships with many of the members of the research team at University of Michigan. These relationships enabled her to contact the right researcher about questions or concerns from particular teachers and principals and to request support from graduate students and LeTUS staff in some classrooms.

Likewise, Chandra James was an essential ingredient in Northwestern's work with Chicago. The decentralized nature of the district meant that teacher recruitment was often conducted by word of mouth and personal contacts. James was clearly well respected within the science education community in the Chicago schools and her word had weight. Reiser noted that when teachers were asked why they had chosen to participate, more often than not they replied, "Chandra told me to come" (Reiser interview, June 5, 2003). Thus in many ways Steel and James *were* the face of LeTUS within their district communities.

One person alone, however, was not enough to fulfill all the professional development needs of the LeTUS teachers in each district. The Center needed to build a larger infrastructure and its staff needed to bring the same careful attention to the design and provision of professional development as they did to that of curriculum and technology.

> We *design* curriculum and technology and then we *do* professional development. That's been the approach, pretty much in all of science education and most of the learning sciences. … It made sense that we declare teacher learning and professional development as an area for close design and development. Just like anything else. And that we employ the same methods to understand teacher learning in this context and try to design better professional development in this context (Fishman interview, June 4, 2003).

Both locations struggled with how to make the professional development activities relevant and satisfying for both novice and experienced LeTUS teachers. As a result, they deepened the work done in those activities to something beyond a simple introduction to the content of the curriculum. Both sites engaged "core teachers" in the design and provision of professional development. By the final year of the grant, nearly all the professional development in both cities was provided by teachers. They noted that this change increased the credibility of the professional development in the eyes of the participating teachers and improved the capacity for showing how practical modifications could be made to suit various classroom contexts. "They're [the teacher leaders providing professional development] saying, 'This is what I did last week and this is how it worked with my kids. This is how I did it last year and this is how it worked with my kids.' So it has a much higher level of credibility for the other teachers" (Steel interview, June 4, 2003). Both sites made summer institutes or conferences available to the teachers. They also provided individual support for those teachers who asked for it,[15] but the cores of their professional development structures were quite different. The deepest component of the professional development offerings provided by the Detroit branch of LeTUS was integrated into the school system's regular professional development infrastructure, while the deepest component provided by the Chicago branch was in the form of graduate course work provided through Northwestern University. These differences are at least partially connected to the centralized versus decentralized nature of improvement efforts in each district.

Graduate course approach: Northwestern University

From their first week-long conference for teachers in the summer of 1998, the Chicago branch of LeTUS had teachers running most of their professional development sessions. The work circle model they used meant there were at least a couple of teachers intimately familiar with each unit from the start. As more teachers used the curriculum, that cadre of core teachers became larger, to include 40 or 50, about 10 of whom were most deeply involved in the work. From this pool, the Chicago branch of LeTUS was able to pull teachers to run their summer conference sessions, kick-off meetings, and graduate courses. Generally researchers collaborated with the teachers on planning and running the sessions; but in most cases the teachers took the lead role.

---

[15] Barbara Steel, Chandra James, and Lou-Ellen Finn (a LeTUS teacher from Chicago who became director of professional development for the Northwestern group in the Center's third year) would go to teachers' classrooms to do demonstration lessons, help with technology and special materials/equipment, provide an extra set of hands, or observe and provide feedback as requested. Graduate students would be called upon to provide similar individual assistance to teachers in classrooms, sometimes while also collecting research data.

Each summer the Chicago site of LeTUS had a one week summer conference. The heart of this conference was a number of break-out sessions where teachers got to see a complete overview of a particular LeTUS unit, including the curriculum and the technology. These sessions were run by teachers who had used the curriculum in the past and always included an example lesson. "You don't just listen to someone talk about the lesson, but people who teach the lessons actually model what you should be doing in your classroom," (Chicago teachers focus group, June 18, 2004). The teachers found these sessions useful for "browsing" the curriculum and deciding which units they might want to try in the coming year.

During the school year, "kick-off" meetings were run once or twice a year for each unit. These were full day sessions that were an in-depth version of the summer conference breakout sessions. "You meet up with a bunch of different science teachers. Some of them are really into inquiry science and some of them, their principals made them go. … You spend a day seeing what the unit is about, doing some of the lessons from the unit and making a decision whether or not you want to buy into it" (Chicago teachers focus group, June 18, 2004). Chandra James organized these kick-off meetings, but teachers experienced with each unit ran them.

In order to provide the teachers with the opportunity to delve into the ideas of technology-enriched project-based science more deeply, Northwestern also offered teachers semester courses (10 weeks) for graduate credit. These courses were usually taught by a LeTUS teacher, but organized and planned in collaboration with Northwestern faculty. In some cases, particularly with very new curricula, the researcher took the lead role. Each course explored one of the LeTUS units in depth. The participating teachers *did* the curriculum in their classrooms as they were learning about it in the course. The classes tended to be fairly small, with about 15 teachers, and met once a week. During that time, the course instructors reviewed the curriculum and scientific concepts related to it for the lessons in the coming week. They also did some of the lessons during the session.

The teachers interviewed seemed generally very satisfied with the courses. A couple recalled one course that did not go as well as the others and even then they felt parts of it were worthwhile, "So even though part of this class was a little bit lacking, the other part was really interesting for us. So it's like even at its worst, it's good" (Chicago teachers focus group, June 18, 2004). Moreover, their experience was that the Northwestern researchers made adjustments when things were not working. "What's nice about Northwestern is … if it's not working for the teachers, then [they] make a change. It's not, you know, 'You adapt to what we're doing!' It's, 'Let's change it so we can get you to buy into it and we'll try to make it better.' So they are highly flexible" (Chicago teachers focus group, June 18, 2004).

The teachers also described the courses as challenging. For example, several of the members of the focus group had been involved recently in a course about the *I, Bio* unit. "It was very challenging. We had lots and lots of reading to do and a lot of writing and chemistry problems," noted one teacher. "And calculations" another added. "And calculations!" the first agreed, "Those were hard." One laughingly mentioned the shock from her students when they heard she had received a “C” on one of the calculation assignments. She and the others felt the knowledge gained was worth the challenge. Said one teacher, “I have taught biology in seventh and eighth grade before but not at the level that the *I, Bio* class hits it. … I got a lot of content that I never would have had otherwise” (Chicago teachers focus group, June 18, 2004). The others agree, “That was a great class. It was terrific.”

The instructors also worked hard to make the links between content knowledge and pedagogy clear.

> It was really interesting. So the researcher was there along with a teacher who had taught the unit. And in his classroom the researcher had done a lot of observations of how it rolled out. So, they had this sort of thing going where they would talk about wearing different hats and say it was either content or pedagogy. So we would go back and forth between those two, not mutually exclusive kind of subjects during the course of an evening. So, we would talk about energy that’s in bonds, hydrogen bonds, for a while and that would be content. And then we would switch to how are we going to teach this to kids? Then we would do an activity. To me it was terrific (Chicago teachers focus group, June 18, 2004).

Exploring the scientific content behind these units was particularly critical in Chicago. The district is largely composed of K-8 elementary schools and 9-12 secondary schools. Illinois certifies teachers as either K-8 elementary teachers or 6-12 secondary teachers with a subject area endorsement. Most of those teachers of students in grades six to eight work in an elementary school and have an elementary certification. How schools organize those who teach in grades six to eight varies enormously, and the district isn’t certain to what extent schools departmentalize in those grades (Mike Lach interview, October 6, 2004). Some of those teachers who end up teaching science may have little or no formal education in science. Recent policy changes have required those middle school teachers with more than 50% of their course load in a single subject to have an endorsement in that subject. However, it will take some time for those already in science positions to get their endorsements. Not surprisingly, more than half of the Chicago teachers interviewed for this case did not have a science background, even among the teacher leaders. Those dedicated to quality science education (and LeTUS) made up for this lack of formal training through passion and study. Thus the content coverage in the Northwestern graduate courses was especially appreciated.

The courses were initially funded by a special grant from Lucent that paid for three of them to be run each year for three years. As part of the course, participating teachers received a laptop computer. This model of professional development was neither continuous nor integrated into the district’s professional development infrastructure. However, it was closely tied to practice and built very deep knowledge of both the LeTUS unit and the scientific concepts related to that unit.

District-based professional development: Detroit

Professional development in Detroit was handled somewhat differently. As in Chicago, Detroit had a regular summer institute in which teachers were introduced to the curriculum. The overall agenda and the general sessions for these institutes were generally planned by a team consisting of key hi-ce researchers along with Steel and Gray. Break-out sessions focused on specific curricula were planned by the point person for each curriculum unit. (See Table 2.) In addition, LeTUS offerings were made as part of the district's regular system of professional development in the form of monthly Saturday meetings. Again, at first, the monthly Saturday sessions were largely run by hi-ce researchers.[16]

However, by the 2000-2001 school year this system was no longer serving the needs of either the teachers or the researchers. The work had scaled significantly since LeTUS began in 1997, and it was no longer possible for the researchers to continue doing the professional development work while at the same time refining the curriculum *and* conducting research. Moreover, the new teachers were not getting the same kind of close support that the original pilot teachers did. Pilot teachers often had researchers in their classrooms both collecting data and providing support during their initial trial of the curriculum. That support sometimes included researchers doing the teaching themselves the first time an activity was tried out. As a result, the teachers worked closely with those researchers on adjustments to the curriculum and its redesign. Through these experiences the pilot teachers gained a deep working knowledge of the curriculum. In addition, they had a very rich, interactive relationship with the researchers and within the small group of teachers involved in the piloting work. New teachers didn't have this kind of support. "It's so big now that the university people can't be there every day. Barbara can't be there every day" (Detroit teacher leaders focus group interview, June 15, 2004). As a result, newer teachers were taking longer to ramp up.

In addition, the teachers were becoming somewhat dissatisfied with the professional development offerings available, especially the experienced teachers. Around the time the project started to scale, some of them felt they were not getting much out of the Saturday sessions. At that time the sessions were still run by the curriculum developers. "It basically was their attempt to help teachers implement what they had written and it wasn't as interactive as it is now" (Detroit teacher leaders focus group, June 15, 2004). In addition to providing information to new teachers about how to do the curriculum, they also got feedback from experienced teachers about it. One teacher leader recalls saying to a colleague, "Well, *they* [the researchers] got a lot out of that. Too bad we didn't get anything out of it." (Detroit teacher leaders focus group, June 15 2004). She went on

> I really felt that they were asking us questions and we were feeding back to them the answers of what they wanted to know, but it wasn't anything that helped us. We have all been to workshops like that for ages (Detroit teacher leaders focus group, June 15, 2004).

[16] Both the summer institutes and the Saturday sessions were run as part of Detroit Public Schools' professional development offerings. According to their contract, Detroit teachers must be paid for their work outside of regular class time. Steel and the central administration worked closely to "maneuver through the bureaucracy and facilitate the scheduling, approval and teacher payment for such sessions" (Urban Impact Award Application, 2004, p. 9).

Barry Fishman had recently begun a program of research focused on the professional development issues within LeTUS. The problem was picked up in his interview with this teacher and passed on to the hi-ce research team and the Detroit district leaders involved in LeTUS. They interpreted the problem as a need to get teachers' voices and experience better incorporated into the professional development.

Because of all these factors, the Detroit site of LeTUS decided it was time to shift the professional development to the teachers themselves. This move would free the researchers time, make it possible to provide more in-depth support to more teachers, and help bring teachers' needs and voices into the professional development design. Fortunately, at around same time a cadre of experienced and dedicated teachers was emerging as leaders within the LeTUS community.

> It was clear we had a group of very committed teachers who were coming to everything. It was like LeTUS was their social life. They came to all of the Saturday workshops. They came to the summer thing. They came to all of the other kind of extra things that we were putting on and they were getting very knowledgeable and when they were meeting with teachers, they were saying "We can't do it this way. We've got to do it this way. And don't let the university tell me that this is a good activity; it's not a good activity. Just don't even bother with those things. Do it the way I think you should do it" (Marx interview, June 4, 2003).

Seven teachers who had shown strong dedication to LeTUS, among them several teachers who had piloted the initial versions of the curricula and continued to serve as curriculum reviewers, were chosen to form a group of "teacher leaders". The group was led by Barbara Steel, but they designed both the monthly sessions and the summer institutes in consultation with Barry Fishman and his team of graduate students.

The first major hand-off was for the summer institute of 2002. As can be seen from Table 2, a number of changes occurred as a result of the move from curriculum designers to teachers as the leaders of LeTUS professional development (Fishman et al., 2003, March).[17]

[17] The following discussion of the changes which occurred as a result of the institute hand-off draws heavily on Fishman et al., 2003, March. Interested readers should see this document for further details.

Table 2 Summary of the effects of changes resulting from shifting responsibility for professional development in Detroit (adapted with permission from Fishman et al., 2003)

Theme Characterizing Change	hi-ce Led PD	DPS Led PD	Value Added by DPS	Challenges Introduced	Adjustments to Challenges
Goals	• Organizers sought to extend teachers' use of inquiry and technology • Curriculum developers sought to extend teachers' understanding of units	• Organizers sought to address DPS priorities, e.g. literacy, alternative assessment, technology, as well as inquiry-based instruction • Lead teachers wanted to provide relevant support for teachers' enactments	• Lead teachers modeled classroom tested activities, addressed teachers' diverse contexts, provided wealth of experiences with units	• Lead teachers' PD planning influenced largely by their personal experiences and beliefs about professional development	• Add to lead teachers' knowledge base so they can think about the broader reform goals as well as DPS and teacher-specific priorities
Use of teacher feedback	• Feedback gathered by curriculum developers while assisting in and collecting data from multiple classrooms used to plan the PD	• PD grounded in the classroom and PD experiences of the lead teachers along with formative feedback collected during the institute	• Classroom activities and strategies described were "classroom tested" by the lead teachers providing the PD • Formative feedback was sought during the session	• Lead teachers not able to base PD on data/ experiences from a wide range of classrooms	Fishman's team brings to planning meetings… • Findings from LeTUS research (classroom observation, student achievement, teacher surveys) • Findings and theoretical ideas from literature on teacher professional development
Planning and organization	• Division of labor: Lead investigators and DPS LeTUS liaison plan overall goals and structure and general sessions; curriculum sessions planned by curriculum developers for that unit • Scope and sequence of institute driven by reform goals	• Lead teachers plan overall organization and both general and curriculum sessions • Scope and sequence influenced by DPS goals	• General and curriculum sessions are well-integrated • Curriculum sessions reinforce DPS priorities	• Less emphasis on extending the use of inquiry strategies beyond the LeTUS units	• Saturday meetings during school year include non-LeTUS as well as LeTUS curriculum

First, the goals of the institute changed. In general, the hi-ce group started with broad instructional reform goals as their priorities. This led them to focus on extending teachers' use of inquiry and technology in general and helping them understand specific units. The teacher leaders' goals, on the other hand, started with the day-to-day needs of teachers in Detroit. Thus they focused on integrating various Detroit Public School priorities (e.g. a literacy initiative) into the LeTUS work and on helping teachers develop specific strategies and techniques to support the enactment of the curricula. The teacher leaders were better able to model classroom-tested activities and address a range of teachers' concerns related to diverse contexts. Also, unlike earlier institutes in which the general sessions were planned by different people than the curriculum sessions, the teacher leaders did all the planning. This led to better integration between the general and curriculum-specific sessions.

There were also some limitations introduced when the teacher leaders ran the professional development sessions. First, they did not have access to observational data from a number of classrooms, as the curriculum designers did, to inform their professional development decisions. As a result, their session designs relied mostly on their own experience teaching the curriculum and some formative feedback gathered during the institute. Also, they tended to put less emphasis on extending the use of inquiry strategies beyond the LeTUS units than did the curriculum designers and researchers.

After the summer 2002 institute, the teacher leaders also began running the Saturday monthly meetings. The Saturday meetings were open to all LeTUS teachers, whether they participated in just one unit or several. In earlier times, the Saturday professional development meetings focused solely on the current upcoming unit of the LeTUS curriculum and in this respect bore some resemblance to Chicago's kick-off meetings. This design had two limitations: (1) it made it difficult to infuse inquiry techniques and technology use beyond the LeTUS units more broadly and (2) it made it difficult to create a professional community among the teachers. Since the LeTUS units did not cover the entire curriculum, some teachers only came to the meeting before the unit they were going to teach. Moreover, those who had taught the unit before might not feel the need to come if the session were run as an "introduction" to the unit. Steel wanted to develop a more continuous and cohesive professional community among the LeTUS teachers and help teachers to see the relevance of what they were learning through LeTUS to the rest of their teaching. They decided to expand the Saturday meetings to cover not only the LeTUS curriculum, but also the upcoming topics and activities for the "standard" Detroit science curriculum. Through this shift in focus, Steel hoped to encourage more regular attendance and thereby develop a strong cohort of professionals (beyond the lead teachers) who could support one another in implementing project-based science supported by technology broadly across the curriculum.

A week before each monthly meeting, Fishman and his team met with Steel and her group of teacher leaders. Fishman brought research data in the form of teacher surveys from last year's professional development related to the curricula they were about to cover, and the results of the prior year's pre- and posttest measures of student achievement for the unit. He also brought summaries of findings from the research on the design of high quality professional development and information gathered from other research aspects of the LeTUS work, such as classroom observations. In this way, they expanded upon the information base from which the teacher leaders could do their session designs. Steel and the teacher leaders used this information to discuss ways they could improve each session from the way it had been run the previous year.

The teacher leaders found the infusion of research data into their work helpful. For example, one of the research projects related to LeTUS is a study of "best practices" in inquiry science. This is a very detailed and close study of a handful of classrooms with strong teachers in them to distill best practices for supporting student inquiry. The findings from this study are fed back to the teacher leaders who in turn include them in the Saturday sessions. "We are able to take from the research and immediately put it to practice and find out best practices and help all the other teachers to try to implement that" (Detroit teacher leaders focus group, June 15, 2004).

The sessions themselves are structured to meet the needs of both new and experienced teachers. Since Detroit's curriculum is a fairly structured one, there are breakout sessions by grade level to review the relevant upcoming curriculum. Each of these is led by a lead teacher who has experience with the curriculum. Teacher-to-teacher interaction is critical. As they cover a unit, they discuss each activity, and teachers share past frustrations, successes, challenges and solutions. This interaction keeps even the most experienced teachers engaged. "It's very helpful because each year you learn new things. That's the thing. I've been in seventh grade three years now. Each year, I've learned something new" (Detroit teachers focus group, June 15, 2004).

The other important component to these sessions was the coverage of science content. Unlike Chicago, the grade 6 to 8 teachers in Detroit are largely housed in departmentalized middle schools. Most LeTUS teachers (70%) were certified in science (Marx et al., 2004). Nonetheless, middle school science teachers are generally responsible for teaching across the major fields of science (physics, chemistry, biology, earth and environmental science, etc.), but generally have a degree in just one of these fields. The content knowledge required to teach a LeTUS unit is extensive and so the science content coverage was critical to these teachers, particularly for units outside their field of training. "I may have a physics background but I'm teaching biology [for this unit] and the professional development may provide somebody who has that background in biology to clear up any misconceptions that I may have or the questions that I have" (Detroit teachers focus group, June 15, 2004).

Researchers played a critical role in supporting the content knowledge needs of the teachers. "They bring content expertise and that's something we lean a lot on now" (Detroit teacher leaders focus group, June 15, 2004). The teacher leaders pointed out that they each have pockets of expertise, "But nobody has the amount of content knowledge across the board [we feel we need] ... but they [the researchers] can bring us that knowledge" (Detroit teacher leaders focus group, June 15, 2004). Thus the teacher leaders often asked the hi-ce group to send a representative to provide support for the content knowledge needed in particular sessions.

The commitment required to be a part of this professional community is extensive. Some teachers were simply not willing or able to give up their Saturdays, even once a month, for such professional development. Those teachers interviewed were enthusiastic about the sessions and said they came to between 75% and 85% of the offerings each year. For some teachers, however, even occasional attendance was not possible. In particular, many young parents were not able to schedule the time. One teacher leader noted

> There is one teacher I know who hasn't been to any of our in-services in the last two years but she still does all the units. She is very good at them and we had tried to get her as a teacher leader. … She didn't feel comfortable with that particular position. … She is a very competent teacher and she's got little kids at home. She said she's just not going to give up her Saturdays and her summers. But I go to the school and she's doing the units (Detroit teacher leaders focus group, June 15, 2004).

The teacher leaders explained that while there are exceptions (such as the teacher described above), often those who do not come or do not come regularly have a difficult time with the curriculum and some give up. Fortunately, they have a core of teachers who continue to come regularly and these provide the expertise base that keeps discussions going. "Those are the teachers who make the professional development dynamic for everybody, because they are always participating" (Detroit teacher leaders focus group, June 15, 2004).

Placing the core of LeTUS professional development within the district's instructional support infrastructure and having the sessions run by district teachers has had a positive impact in several ways. First, the teacher leaders are aware of the different instructional initiatives within the district and can incorporate these within their professional development offerings. For example, a coupleof years ago, the district began a large literacy initiative. The teacher leaders incorporated issues related to this initiative into the LeTUS professional development. Word walls were one strategy for vocabulary development being adopted throughout the district, so the teacher leaders incorporated word walls into the LeTUS professional development. "If you look at the LeTUS teachers compared to teachers who are non-LeTUS, they are probably implementing it much stronger than the rest of the district" (Detroit teacher leaders focus group, June 15, 2004). Later, when there was a big push for students to do concept mapping, teachers incorporated that as well, using the word walls as a way to support students' concept map work in science.

Second, the expanded monthly meetings that covered both LeTUS and non-LeTUS topics led to inquiry-based strategies spreading beyond the LeTUS units. The teacher leaders note that science instruction in Detroit has been moving toward a more inquiry-based, constructivist approach for years, but that LeTUS did much to deepen that work. "This program took us a step further and that helped us. Even in the other things that weren't LeTUS units, I think we've tried to make them more inquiry-based. … Trying to make it more like a LeTUS unit with the driving question board and the word wall and that kind of stuff has kind of gone across the whole curriculum now. It's not just LeTUS stuff anymore. It's part of all the curriculum now" (Detroit teacher leaders focus group, June 15, 2004).

Finally, a community of teachers has developed who know one another well and can turn to each other for advice and support. "The community thing is fabulous, even on KNOW [an on-line professional development support system designed by Fishman's team to augment the in-person offerings], sometimes you can go and look and say, 'Oh, okay, they addressed this problem that I'm having.' So you always feel that you can communicate with someone" (Detroit teachers focus group, June 15, 2004). The exchange of ideas and strategies among the teachers often leads to, "These huge ah-hah! moments in the workshops" (Detroit teacher leaders focus group, June 15, 2004). And the teachers clearly value the access they have to this professional community.

The researchers, however, still play an integral role in the professional development offerings in Detroit. Fishman and his team continue to help the teacher leaders plan the professional development offerings. Members of the hi-ce team continue to participate in a support role, particularly with regard to subject matter knowledge. Moreover, as new units are introduced, the sessions for those units tend to be led or co-led by the researchers/curriculum developers until some number of teachers gains sufficient expertise with them to feel comfortable providing leadership. Thus, rather than a simple hand-over of power, the leadership of professional development in Detroit is a shifting shared space to which both researchers and practitioners contribute knowledge, expertise, and time.

As with the new ReNUE work circle discussed earlier, the evolution of professional development in Detroit reveals much about the way researchers and practitioners interacted within LeTUS. The researchers' knowledge base, while respected by the participating teachers, was not sufficiently localized or attuned to daily classroom realities to meet their professional development needs. At the same time, the teacher leaders' knowledge base needed expansion beyond their personal experience if they were to be able to meet the wide range of needs of their fellow teachers and expand the work beyond the specific LeTUS units. By each bringing their own expertise to the task, they were able to improve upon the professional development offerings. They also created a system in which those offerings were continually improved based upon a combination of teacher feedback, classroom research, and findings about student learning. By listening to one another and remaining attuned to the advantages and limitations of their professional development designs over time, they have been able to marshal the evolving capacity of both researchers and educators in Detroit to make critical adjustments. The result is a system that teachers feel serves themselves and their students well. As one teacher explained

> They [the researchers] actually listened .… They made that turn around and started saying, "Okay, what is it you need?" It's not that we still don't give them back what they need too, but it's not the number one priority anymore, I think. What we need and what our kids need seems to be the number one priority now (Detroit teacher leaders focus group, June 15, 2004).

Impact of the professional development on LeTUS teachers

Those teachers interviewed at both sites greatly valued the professional development opportunities provided by LeTUS. They appreciated belonging to a dedicated professional community. "I met terrific people such as the ones in this room that for me really form a professional community and that's something that's missing for me in my school. … Who do I reflect with? Who do I bounce ideas off of? Who is excited about a new inquiry lesson that we could adapt to our purposes? etc. … I think that that's a real important piece of it" (Chicago teachers focus group, June 18, 2004). They felt the support provided was solidly grounded in the realities they would face in their own classrooms and were grateful for both the content and pedagogical knowledge provided. A few went so far as to describe the experience as leading to profound changes in their teaching beliefs and practice.

> For once, one of the education words began to have real meaning to me. What did it mean to be facilitator as opposed to teacher? … We were responsible as a learning community for gathering knowledge and talking about that knowledge and challenging each other about that knowledge. In my classrooms, it was even more interesting because we had some kids who didn't speak English and we had me who didn't speak Spanish and we had other kids that didn't speak Spanish. But it worked. … At the end of the year, the kids were challenging each other for evidence. … It became our responsibility to look and to question and to gather and figure things out together. That's what this involvement did for me. It's beyond the curricula. It's beyond anything. It really opened up my joy in teaching science because it became authentic work that we did together (Chicago teacher leaders focus group, June 16, 2004).

Those interviewed, however, were some of the most dedicated LeTUS teachers — teacher leaders and teachers who were interested enough in the program to attend a focus group interview during the last week of classes. While their strong testimonials are important, a broader understanding of the influence of LeTUS professional development is necessary. The impact of LeTUS professional development can be gauged in several ways: participation rates in both professional development and in LeTUS as a whole, impact on practice, effects on student learning, and extent to which LeTUS teachers contribute to science education leadership in each district. Each of these possible influences is explored below.

Participation rates

The LeTUS curriculum units are optional in both districts. Participation in LeTUS was voluntary in Chicago and semi-voluntary in Detroit, where Gray chose schools to be involved and principals in turn encouraged or required teacher participation. As a result, the professional development offerings (especially the "overview" kind) were not only a means of support, but of recruitment, particularly in Chicago. Thus one measure of their success is the extent to which the curricula are used and teachers return for more professional development. Unfortunately, estimating curriculum use is somewhat difficult since it is not clear to what extent teachers who no longer participate in professional development and are not in some kind of contact with project staff continue to use the materials. The researchers at the University of Michigan consider any teacher who turns in a pre- and/or posttest to be using the LeTUS curricula, even if they don't show up to professional development offerings. Using this metric, they estimate that approximately

30% of Detroit middle school classrooms use at least one of the LeTUS units and that 25%-30% of middle school students are enrolled in these classes.[18]

Participation can also be measured in terms of those involved in the professional development. Toward the end of the LeTUS grant in June 2003, Fishman believed there were 85 teachers involved in the professional development work and they had worked with around 100 altogether. They had few teachers drop out once they started and most of those did so because they retired or moved to another district. Through the end of the grant and beyond, they continued to have teachers interested in joining and those who wanted to take leadership roles. “When I have other teachers who are not in LeTUS call me and say, ‘How can we get in the program?’ then I know that other people are talking about it and having good things to say” (Steel interview, June 4, 2003).

In Chicago, the numbers were a little harder to pin down. Finn estimated that 50-70 Chicago teachers were involved in any given year, but the turnover rate was fairly high. Most teachers came to the workshops or kick-off events just once. Likewise, many teachers took just one Lucent course. The computer was apparently a big motivator to take the course, but it didn’t necessarily lead to continued involvement. “Some of them may have come to the summer conference and then done a different curriculum the following year. But by and large, the greater portion of them … didn’t do a second unit” (Finn, teacher leaders focus group, June 16, 2004). Since many of the faces she saw at these events were new ones, it was hard to estimate how many teachers continued to participate. Shrader and Finn believe the total number of teachers involved over the course of the Center was around 200. However, the typical Chicago LeTUS teacher was only clearly on the Center’s radar screen for about eighteen months. Shrader guesses that of those who stopped coming to regular LeTUS professional development, about 25% probably continued to use the LeTUS curricula, while the rest were “caught up in the next big thing” (Shrader interview, June 6, 2003). On the other hand, the core of 40-50 teachers who continued to participate form a strong “professional network of teachers inside of the Chicago Public Schools who get to know LeTUS, who run our courses, and who run our professional development” (Shrader interview, June 6, 2003). Among them, a subset did a number of the Lucent courses and have developed both a deep and broad knowledge of the LeTUS curricula. Many of them now serve in leadership roles in the Chicago Mathematics and Science Initiative.

The differences in participation rates between the two districts are probably at least partially related to the different district structures and the different ways in which professional development was provided in each district. Because participation was entirely voluntary in Chicago, recruitment was a stronger issue there than in Detroit. The summer conferences and kick-off meetings in Chicago were as much about encouraging new teachers to try the curricula as they were about providing support to those who had already signed on. Moreover, because the professional development in Chicago was generally provided on a unit-by-unit basis (each Lucent course focused on a particular unit, kick-off meetings were aimed at particular units, etc.), it is likely that many teachers

---

[18] Of course, there may be other teachers who use the curricula, but do not turn in either a pre- or posttest, but these would be harder to track, especially if they do not attend the professional development sessions.

thought of it as a typical one-shot workshop and not as an entry point into a professional community.

As a result, Chicago engaged approximately twice as many teachers as Detroit in its professional development offerings, but had a more difficult time creating a continuous professional community among those participating. The core teachers with high participation rates found community when involved in the LeTUS work, but there was no infrastructure in place for maintaining those relationships between workshops, work circles, and Lucent courses. “Unless I have that kind of support from a colleague in the system, I think eventually the layout of the curriculum, the glitches of the technology are going to discourage me” (Chicago teacher leaders focus group, June 16, 2004). Many believed they could continue the work they’d started, regardless of whether or not the researchers were involved, if only they could maintain the professional contacts. However, the less continuous nature of the professional development offerings in Chicago made that difficult. Detroit’s professional development system of regular Saturday meetings aimed at improving science instruction overall provided more continuity and was more successful in creating community, but it also required a greater commitment on the part of participating teachers. While the Chicago version was not as continuous, it was also more accessible to a wider number of teachers.

Teacher growth

In Michigan, the researchers have looked at trends in student learning over time as a way to measure improvements in individual teachers. The trajectories varied greatly. Some teachers had slow, but steady improvements in their students’ learning gains, others experienced periods of little to no improvement followed by sudden, strong gains and still others showed no improvement at all. Overall, however, they were pleased with the impact that involvement in LeTUS appears to have on teaching as measured by student achievement.

They also looked at teaching practice directly in a subset of the classrooms. Fishman and his students studied the links between professional development, teaching practice, and student achievement. They showed with this work that pre- and posttest data from the previous year can be used productively in professional development sessions to pinpoint areas with which students are having difficulty and generate discussion of possible teaching solutions. These discussions in turn led to real changes in classroom practice and improved score gains between pre- and posttests (Fishman, Marx, Best & Tal, 2003). Likewise, Blumenfeld and her team were working with a small number of teachers on closely examining specific teaching strategies that make the units more effective ones and collecting research data on these efforts.The Northwestern team also attempted to collect direct data about the enactment of the LeTUS curricula. However, the number of classrooms involved made it difficult to collect such data in a comprehensive fashion. Based on her observations of teachers in LeTUS classrooms and LeTUS professional development activities, Finn believed they had changed teacher practice in positive ways. And some teachers reported being able to attract their own grant money based on what they’d learned through LeTUS. “I just got a Toshiba Grant this year. … [It was written up] pretty much in the style of the LeTUS curricula and that’s what they liked and were willing to fund. … They were really excited. I got phone calls and everything" (Chicago teachers focus group, June 18, 2004). Finally, individual projects and student theses looked closely at some classrooms. However, their formal data collection on teacher practice in Chicago was not a robust one from which they could make generalized statements across the site (Gomez interview, June 6, 2003).

Development of leadership in science education

The LeTUS professional development offerings in both Chicago and Detroit led to the development of science education leadership deemed important by district leaders in each school system. Under Gray's leadership professional development offerings in science have long been considered strong within Detroit. "We're science so we kind of lead the district in professional development," explained one of the teachers (Detroit teachers focus group, June 15, 2004). Added another, "They send social studies people to our workshops to see what we do" (Detroit teachers focus group, June 15, 2004). The Detroit USI was an umbrella for deepening this work through a number of science improvement efforts. Those teachers who attended the LeTUS workshops were generally those the interviewees saw at the other science workshops in the district (Detroit teachers focus group, June 15, 2004). It is definitely true that the LeTUS teacher leaders and core participants (who are the teacher leaders to be) form a strong leadership network for science education in Detroit. However, it is a bit difficult to disambiguate the role LeTUS played in building that cohort from the professional development offerings in science at large. At the very least, LeTUS served to deepen their knowledge of inquiry science and learning technologies as well as provide the teacher leaders with more training in the provision of professional development.

In Chicago, the role of LeTUS in the building of science education leadership is much clearer. Many of the leaders within the district's new Chicago Mathematics and Science Initiative (CM&SI) were part of LeTUS-related work. Michael Lach, a Chicago educator who took a two-year leave to work with Danny Edelson on the development of high school environmental science curriculum was hired as the Director of Science for the Initiative. Chandra James, the former LeTUS liaison for Chicago, is the Elementary Science Manager for CM&SI. Lach said that a significant number of the Initiative's leaders have participated in LeTUS. These leaders include district staff, special coaches, and lead teachers in schools. "I think it [LeTUS] has been great for Chicago. I mean, it's been the only place we have that has developed teacher leaders in science" (Lach interview, October 6, 2004).

Comparisons and implications

There are many similarities between the professional development systems employed at the two sites. However, the structure and integration of the deepest professional development offering at each site – the Saturday sessions in Detroit and the Lucent courses in Chicago – differed dramatically and these differences were rooted in the district contexts. With its centralized structure and history of strong professional development in science, it made sense to incorporate LeTUS professional development under the district's umbrella in Detroit. This strategy would probably have been difficult to mount in Chicago. The Lucent courses, run outside the district's structure, however, worked well.

While the overall structures of these offerings were quite different — one was a 10 week graduate course leading to course credit and a computer upon completion, the other (paid) participation in an on-going professional community outside of regular work hours — many of the strategies used within them were similar. Both reviewed the curricula, covering pedagogy, teaching strategies, and science content. Both trained teachers to use the associated technologies. Both engaged teachers in examining some of the lessons by working through them as students. And, finally, both had teachers talk together about their experiences working with the curriculum. Some of the details are different. For example, participants in the Lucent courses received grades, while those in the Detroit Saturday sessions did not. But in general, the *kind* of knowledge and experience they were receiving was similar. The biggest difference, then, was one of access, participation, and community.

As noted earlier, the monthly Saturday sessions required significant commitment on the part of teachers, not all of whom would be willing to give up their personal time for this kind of work, even when paid. It may be particularly difficult for mid-career teachers with young children. In contrast, the Lucent courses required a shorter term commitment, but they were limited in their ability to foster an on-going community. Thus, while both approaches were effective in creating a cadre of strong inquiry-based science teachers for their districts, they each reveal issues related to scaling this work. The Detroit model may be limited in the number of teachers it can affect, while the Chicago model may be limited in its ability to create a sustained professional community. It is tempting to speculate that the ideal solution might be to have both forms of professional development available. However, such a solution would likely tax the capacity of teacher leaders within a district to provide such support. Moreover, this solution would only be possible in districts for which both options were viable. The Detroit strategy would be difficult in districts that do not financially support teachers for out of time work, or who do not have a well coordinated professional development infrastructure. Likewise, the Chicago strategy might not work without the extra funding that provided teachers with incentives to take the graduate courses. In the end, districts and district-research partnerships can at best put together professional development strategies that maximize impact given their particular constraints and resources.

Those concerned about bringing this work to scale might also note that even though by the end of the grant the bulk of professional development was provided by district staff and teachers, researchers remained involved in at least planning and often attending, supporting, or co-delivering that professional development. The educators interviewed believed that the researchers brought substantial knowledge of both pedagogy and science content to the professional development. Interviewees noted that many of the instructional strategies they employed in LeTUS classrooms originally came from the researchers — either through the curriculum design or the professional development offerings. They saw their job as both identifying which of these strategies were promising in real classrooms and then adapting them to work in a variety of classroom contexts. Professional development opportunities that allowed them to discuss such adaptations with their fellow teachers were critical to that work and fed into the continual redesign of both the curriculum and professional development.

Having researchers involved in the professional development offerings provided a conduit to big ideas with respect to pedagogy from the scholarly literature as well as an easy path back to curriculum redesign. Likewise, the researchers were considered important sources of science content knowledge, a critical issue given the demanding nature of the science content in the units and the sometimes fragile knowledge base some teachers had with respect to that content. Providing teachers with access to this knowledge from sources other than the researchers then becomes a critical issue when scaling this work beyond the current LeTUS configuration of two districts and two research teams. Likewise, alternate routes for feedback into the curriculum redesign or at the very least to local adaptations of the curriculum become an issue when researchers are no longer in regular contact with practitioners. As they work on post-LeTUS expansions of the work, the LeTUS researchers are already beginning to think about these and other issues related to scale. (See the section entitled "Beyond LeTUS" below.)

LEARNING THROUGH AND FROM DESIGN: RESEARCH

A central commitment of design-based researchers is that their work foster advances in both theory and practice. Thus it was important to the LeTUS researchers that their work had academic merit, theoretical coherence, and was known and respected by colleagues. They felt they made progress on all three fronts (Marx interview, June 2003). They also believed the amount of learning that they as researchers had done through this work was important. In particular, they noted that they have learned a great deal about what is *really* possible with respect to project-based science in classrooms (Krajcik interview, June 2003). They saw these achievements as being reflected in their success at publishing their findings and insights from the work, as well as in their ability to receive funding to continue and extend it. Indeed, as of March 2005, the researchers involved in LeTUS were principal or co-principal investigators on at least sixteen active grants either directly or indirectly related to the LeTUS agenda awarded from the National Science Foundation alone.

Getting there was not easy. Engendering and studying large-scale science reform in urban districts is an enormous endeavor. Not surprisingly, there were a number of challenges to conducting the research end of LeTUS. First, doing research within urban districts is a tricky business, especially research with the kind of scale and visibility of LeTUS. When crafting their data collection and reporting procedures, the LeTUS researchers needed to be aware of and sensitive to the bureaucratic structures each district had established for research conducted within its system, the effects of the intrusiveness of data collection on the educators' work and student activity, the data needs and desires of the district personnel, and the political realities each school system faced.

Second, it took a while to build the research context itself. Productive relationships with district educators needed to be forged and the initial designs put in place before the most critical empirical work on teaching practice and student learning could begin. The researchers also had to develop research plans and instruments that were tenable at this level of scale, yet still provided them with the design insights they needed for improving their work. Moreover, those instruments had to be responsive to current nation wide emphasis in educational research for traditional quantitative studies.

Finally, the researchers had to balance their time between the various roles they played within LeTUS and the various research projects related to the Center's work. They served as curriculum developers, materials producers, professional development providers, technology builders, gurus and trouble-shooters, and finally, researchers and scholars. This range of roles led to an on-going tension for the researchers between providing "service" and conducting research.

> One of the bigger challenges of work like this generally and for this project is maintaining a good balance between doing something you want to call research and how you want to identify that and something you want to call service and how you get value out of that and how the people you work with get value out of that, and I think they are always in tension (Northwestern researchers focus group, June 18, 2004).

The balancing act also includes a considerable amount of basic management. In addition to the main grant that established the Center itself, the researchers were working on a plethora of both previous and new grants, most related either directly or indirectly to the LeTUS agenda. Managing the finances for this constellation of funding, coordinating the research and development activities, overseeing staff, coordinating among the various project participants, and continuing to acquire new funds to maintain their infrastructure all put pressures on the researchers' time.

At the core of this set of challenges is a disjoint between the structure of their work and the kind of scholarly products researchers are used to creating. The activity in LeTUS was structured to support a collaboration among the four institutions and their members, to continually keep their endeavor one of mutual interest and benefit. But this structure made it difficult for the researchers to *write* about their work.

> You have to persevere and keep the relationship going over the long haul by continually reinventing the relationship and building it around new tasks to engage in. That's very important and it's incredibly frustrating because most academics build their research programs around a series of studies. But what LeTUS did, is it built the activity around a set of practices, which meant that you had to carve up the territory of practice into things that look like studies (Marx interview, October 1, 2004).

Part of the solution to this challenge was creating the capacity within the participating researchers for parsing their practice into studies. The more senior researchers had experience doing so, and part of their mentorship to the graduate students and young scholars was helping them learn the same skills (Marx interview, October 1, 2004). In other cases, however, they believe they still have not yet developed an adequate way of describing the key findings from their work. "Most of the stuff we publish doesn't capture, in my opinion, the complexity of what we try to do" (Northwestern researcher focus group, June 18, 2003). Thus they feel that part of the solution may be a need for new models or genres of research reporting that better portray the essence of what they are learning (Gomez interview, June 6, 2003; Northwestern researchers focus group, June 18, 2004).

While researchers at the two sites have written papers together, they did not collaborate on data collection and analysis. Each site designed its own research infrastructure. They each faced the set of challenges described earlier but handled them in different ways. There were some similarities across the two sites. At both universities, data collection, analysis, and writing occurred in three layers — thesis work of individual graduate students, studies done by sub-projects within each site, and site-wide research. Both created pre- and posttests linked to the curriculum materials. And both did investigations of the links between student motivation and academic achievement. But otherwise their research endeavors were quite different. The research interests and structure of the local districts had a significant impact on the design and accomplishment of the research they conducted, as did the organizational structure, expertise, and interests within each research team.

The rest of this section outlines the major aspects of this research work, including: the role of the research interests and structure of the local districts, the major issues associated with the creation of the research context, the means of organizing and coordinating the work at each site, LeTUS's contributions and publications, and the implications of participation in LeTUS for development of young scholars.

Research interests and structure of local districts

The challenges of conducting research in large urban districts are well known to both researchers and district leaders. One of the district leaders in Chicago explains those challenges as follows:

> Massive bureaucracy. Our data structures are weak. It's hard to find who to talk to. We get paranoid about letting people in because it might show us up, given the politics here. There is not a culture that really says, "Data is important." I mean, everybody says, "We want data-driven decision-making," but nobody knows exactly what that means or how to do that. When everybody is trying to do so much with so little, it's hard to find the extra time to sit down and do an interview or fill out a survey or to think carefully and critically about something" (Lach interview, October 6, 2004).

Beyond these general challenges, each local district involved in LeTUS had its own affordances and challenges for the conduct of research related to the accountability frame in which each functions, the kind of audience each provides for the researchers' findings, and ease of access for conducting the research.

Accountability context

The accountability contexts were quite different in Chicago and Detroit. As mentioned earlier, the combination of site-based management and a focus on mathematics and literacy achievement made systemic improvements in science teaching and learning a relatively low priority for the Chicago Public Schools during the time LeTUS was funded. Indeed, a state test in science was not initially available in Chicago when LeTUS began and the optional city test was not administered in most schools. Later, when the state began testing science in seventh grade, the scores in that subject were still not a priority for the district.

In contrast, city and state mandated tests in science existed and had real currency for both district leaders and principals in Detroit. Moreover, as the district's USI evolved through a new round of funding from the National Science Foundation into the Detroit Urban Systemic Program (1999), LeTUS helped provide the research required for the USP (Gray interview, June 14, 2004).[19] The hi-ce team's research design was informed by this knowledge and thus more driven by district needs than was that of the Northwestern team.

Interest in research findings

The two districts also differed substantially in the extent to which they wanted to hear about findings from the Center. In Chicago, the research team did not feel a strong mandate to produce evidence of student achievement for the district. First, it was not clear to them to *whom* they would report such data. Their district partner was the Chicago Urban Systemic Initiative (CSI). However, they did not feel accountable to this group for demonstrating the impact of their work. The CSI largely helped them identify schools and teachers with which to work and facilitated some of their efforts by assisting with the provision of resources, such as technology or teacher time. There was no clear sense that *Chicago* as a whole was making a decision whether to be a part of LeTUS. "To the extent that we had any accountability at all, it was to individual schools or teachers" (Northwestern researchers focus group, June 18, 2004).

Second, given district priorities at the time, it was not clear to what extent *anyone* (other than participating teachers) was interested in improvements in science achievement. As LeTUS was just starting its work, Gomez spoke with Tony Bryk, a researcher then at University of Chicago with extensive experience studying the Chicago Public Schools. He reports that Bryk told him

> "My advice to you guys is, given that you care about science and science is like a non-entity in Chicago, you'd better figure a way to connect your work through reading and math if you want anybody to pay attention" and in many ways it [Byrk's advice] proved prophetic (Northwestern researchers focus group, June 18, 2004).

The researchers did make an argument to Chicago schools and teachers that LeTUS had the potential to improve students, reading and mathematics scores, "But we weren't ever asked to turn around in LeTUS and document that" (Northwestern researchers focus group, June 18, 2004). Once the state test in science was in existence, teachers who joined the project were concerned about whether LeTUS would have a positive impact on their students' scores. However, showing them the relationship between the curriculum and the *Chicago Academic Standards and Frameworks* was a sufficient answer to their concerns.

In contrast, the hi-ce team *knew* their audience was Gray and her team along with the participating principals and teachers. The district was eager to hear about the effects

---

[19] Detroit Public Schools worked/works with several research institutions for both their USI and their USP, each of which has been a district-wide effort across all grade levels. LeTUS only ever affected the middle school grades.

of LeTUS curricula on student achievement and there was a clear expectation that such information be made available. "As we moved forward in the project, we were looking at how the whole LeTUS effort assisted with test scores. As we evaluate that data, we are on an on-going basis trying to look at those strategies that are working better and have improved student learning" (Gray interview, June 14, 2004). Each spring, Steel coordinated a time for the Center team to meet with principals from participating schools. In addition to conversations about how to best support the teachers' LeTUS work, these meetings included reports on the effects of LeTUS on student achievement. In particular, the principals were interested in data that showed students in LeTUS classrooms outperforming other students, both within the same school and across the district.

As in Detroit, LeTUS researchers from Northwestern met periodically with the principals of participating schools to get feedback from them and discuss how the work was going. These meetings, however, did not focus on research findings for the most part, but rather logistics of making LeTUS work in their schools. Thus they discussed such issues as which teachers were the right ones to work with LeTUS and what was the best way to give them technology access.

In addition, both sites also provided teachers with the results from the pre- and posttests. As outlined earlier, teachers seemed to find these results interesting.

Procedures for gaining research access

While the educators in Detroit clearly had a vested interest in LeTUS's research efforts, getting those research plans approved was a bit more challenging than in Chicago. All research conducted in the Detroit Public Schools must go through an approval process conducted by their Office of Research, Evaluation and Assessment. This approval process can take some time. In particular, researchers are not to appeal directly to teachers or principals for willing participants. Rather, once the research has been approved, the Office of Research, Evaluation and Assessment sends an invitation to the principals of the schools to which the researcher hopes to gain access, inviting them to participate. When the principals have responded, the office then informs the researcher of which schools and teachers s/he may contact.

This system protects schools and teachers from being bombarded with requests, enables the district to ensure that the research being conducted is well thought out, and ensures that all the critical parties are apprised of any important research activities. However, it takes a considerable amount of time. Each study the hi-ce researchers conducted related to LeTUS needed to go through this approval process, and the district collaborators were critical to getting that work done on a timely basis.

> We had on-going meetings with the LeTUS faculty along with our staff here so that we would know when certain deadlines would occur and what needed to be done to move the proposals through. Generally, I would trigger the approval of parents because if they were experiencing something different in their classrooms, we contacted parents to let them know and that if they had any concerns about it, that they could request their students not to participate (Gray interview, June 14, 2004).

In addition, Steel helped identify possible participants and keep them apprised of the approval process. Even with this assistance, the entire process of both locating participants and getting the research approved could (in some cases) take months, leading to a relatively small time frame for conducting the research before the end of the school year.

In contrast, the procedures in Chicago appear simpler, with research approval being a process of acquiring agreement from the key participants, including district leadership involved in the affected program (e.g. the Chicago Systemic Initiative). The most labor-intensive part of the process of gaining access was initially convincing schools and teachers to participate. The CSI was helpful in pointing out schools with leaders, teachers, and infrastructure that might be a good fit for LeTUS, but most of the recruiting work was done by the researchers. Given the high turnover rate among Chicago teachers participating in LeTUS, recruitment was a continuous effort.

Thus, while the approval process was more complicated in Detroit, the tight and highly interested involvement of district personnel led to a fairly close working relationship around research at that site. In Chicago, where the district had less of an intense interest in the research findings and the researchers needed the district personnel less to accomplish the work, the research relationship was a looser one.

Creation of the research context

Creating the research context in LeTUS included building relationships between the four institutions, crafting the pedagogical innovations (i.e. curricula and associated professional development), setting up the technological infrastructure and producing research instruments and procedures. Each of these activities takes time and is part of the reason design-based research has a fairly long publication lag. As has already been discussed, both sites were quite successful at setting up the first aspect of the research context – the pedagogical innovations. However, each had difficulty setting up a technological infrastructure and they faced some challenges crafting their research instruments and procedures.

LeTUS had difficulty creating reliable access to computers and the internet in many of the participating schools in Chicago and Detroit. Technology in school districts is typically overseen by technical staff used to supporting an administrative information infrastructure for maintaining student and employee records, accounting data, and so on. They are not accustomed to thinking about the instructional purposes of computing (University of Michigan researchers focus group, June 14, 2004). Thus the LeTUS team ran into problems such as firewalls which barred students from accessing important websites on the internet, and computers or network systems that often did not function properly because the administrative systems received first priority. Even when computers and internet connections were available, they were often located in labs or other shared spaces with many teachers and students vying for their use. Without regular access to computers, teachers do not have the opportunity to develop experience and fluency with technology and may find supporting students' use of it in class difficult (University of Michigan researchers focus group, June 14, 2004). The research teams in both locations poured a lot of effort into trying to combat these problems. However, even with willing and supportive collaborators inside each district, they could not break down all the barriers.

> I used to go down [to the Detroit Public Schools offices] frequently to talk to Gray, but Eliot [Soloway] would go down there as frequently, if not more, to talk to the person in charge of technology. He literally put in blood, sweat and tears. … I think to this day, there is still not access to technology for most teachers [in the Detroit Public Schools]. … That was the biggest challenge and probably the biggest heart break (University of Michigan researchers focus group, June 14, 2004).

In the end, they mostly managed temporary work-arounds (e.g. allowing teachers to borrow sets of laptops to use in their classes for particular lessons; or purchasing direct internet feeds for individual schools out of the districts' LeTUS project funds) but never came up with satisfactory permanent solutions. As a result, the teachers sometimes had great difficulty doing the lessons in each unit that required technology.

They also met challenges creating a research infrastructure to support their efforts. The set of changes they were putting into place were numerous and provided countless potential avenues for study, not all of which could be explored. Each site tended to focus on particular aspects of the design work. For example, Northwestern spent more time documenting their curriculum design process than did the hi-ce team. On the other hand, the hi-ce team spent more time documenting the design and evolution of their professional development system than did Northwestern. These kinds of choices aligned with the research interests of particular faculty and graduate students at each site. However, both sites had to contend with the general problem of creating research plans and instruments tenable at this level of scale. For example, when describing the challenges of building sound assessments that could be used in large numbers of Chicago classrooms, Herman and his LeTUS colleagues note an important shift they had to make in their own thinking about how to best measure student learning:

> These "realizations" [about test format, item difficulty, etc.] may seem trivial to some readers, but they represent a difficult but important shift for those in our research tradition. We believe in engaging individual students in meaningful scientific inquiry, and in fostering deep conceptual change. Within this tradition, qualitative methods focused on relatively small numbers of students are the norm. But, as we have attempted to evaluate the impact of LeTUS units on students' learning in hundreds of classrooms, we have increasingly felt the need to develop and administer written tests to students, with relatively straightforward items (Herman, MacKenzie, Sherin & Reiser, 2002).

They faced a parallel challenge when it came to understanding the effects of their work on teacher practice. While capturing in-depth understandings of teaching practice in a few classrooms was an activity with which they were well familiar, coming up with manageable data collection routines that provided richer data than teacher questionnaires and allowed them to draw broad generalizations about the effects of their work was difficult.

A final issue with the creation of their research infrastructure was the changing policy context with respect to educational research. Historically, much of design-based research has been focused on learning goals, such as the ability to craft explanations based on scientific evidence, that are not simple to assess using methods which are affordable and manageable for large-scale purposes, such as state accountability testing. The assessment community has been grappling with this problem (Pellegrino, Chudowsky, & Glaser, 2001), but in the past design-based researchers generally used their own instruments instead. These instruments were designed to capture the kinds of learning their innovations are meant to encourage. As the quotation above suggests, such instruments tended to be too labor intensive to use on a wide scale. They were also not part of the accountability scheme to which most districts are now responsible. As mentioned earlier, LeTUS began after the standards movement was well in place, but before the accountability schemes which followed had been fully realized. Once the *No Child Left Behind* legislation came into effect part way through the grant, the push to demonstrate the worth of innovations in terms of state tests became stronger. Moreover, research designs that looked more like randomized controlled studies were being emphasized by government funding agencies. The work of the research teams needed to be responsive to these changes. For example, they found it important within this context to demonstrate that doing well in a LeTUS classroom also translated into doing well on the high-stakes tests administered within each district. Moreover, by the end of the grant, they were exploring, and in some cases implementing, research designs that included non-LeTUS comparison classrooms, particularly in Detroit.

Organization of the work

As one researcher noted, the core contrast between the organizational structures of the two research teams is apparent from a sign on the wall of hi-ce's meeting room at University of Michigan (Reiser interview, June 5, 2003). Below the name of the center on this large, well-made plaque is a list of numerous projects, including the names of the funders for those projects. LeTUS is just one of them. Formed by Blumenfeld, Krajcik, Marx, and Soloway about ten years ago, hi-ce both labels and institutionalizes an enduring collaborative relationship among these University of Michigan researchers. Fishman joined the group when he came to University of Michigan as an assistant professor in 1997.[20] LeTUS fits within this trajectory of hi-ce's on-going joint work.

Among them, the members of hi-ce have a wide range of background experience and research interests. Those interests overlap, and on any given project they may each wear multiple hats. However, over the years, they have also each created fairly consistent core roles to play within their collective research. Krajcik's background is as a science educator. Thus he took the lead role with respect to curriculum development on LeTUS. Soloway is a computer scientist and took the lead role with respect to software development and experimentation with new technologies. Blumenfeld is an expert at classroom observation techniques and oversaw their classroom-based research. She does not get involved in many of the management aspects of their collective work and instead is "sort of the official holder of our writing agenda" (Marx interview October 1, 2004). Marx is an educational psychologist and oversaw their quantitative data collection and

[20] There are other researchers involved in LeTUS or hi-ce related work, but these five seem to be the most central.

analysis. Professional development was originally overseen by a combination of Krajcik and Marx, but as Fishman developed an interest in that area, he took it over. Finally, Marx served as the bridge between all the members of the team.

There has been a lot of discussion in the literature recently about what design-based research is and the methods and processes employed by design-based researchers (e.g., *Educational Researcher,* 1993; *Journal of the Learning Sciences*, 1994). The hi-ce group doesn't worry much about these debates. They simply employ the methods that make the most sense to them given the research questions they are exploring. Among them, they have a wide methodological base. Krajcik was well trained in clinical methods in science education. He knows how to interview children and use analytic tools like concept mapping to get at their science understandings. Blumenfeld is described by her colleagues as a master of classroom observation. Marx also has skill in classroom observation and is a strong quantitative analyst. "So we had enough skills in our group to just take on whatever methods that we needed to take on. … We felt very secure that we could use methods and adapt methods that were appropriate" (Marx interview, October 1, 2004).

In contrast, LeTUS *was* the umbrella organization holding together the work of researchers at Northwestern University. This is not to say that they did not previously engage in collaborative research. Many of them had worked together in the past, but usually only two or three of them at a time for any given project. LeTUS was the first time so *many* researchers at Northwestern had come together for such a long span of time and with the intention of creating an enduring infrastructure.

The core LeTUS research team at Northwestern — Gomez, Reiser, and Edelson — was smaller and somewhat more homogeneous than that at University of Michigan. Reiser and Gomez are both cognitive scientists by training and Edelson's training was in computer science and the learning sciences. None of them had a deep history of work related to large scale field studies like that of Marx, nor the science education background of Krajcik nor the classroom methods focus of Blumenfeld. Expertise in these areas was brought into the team through post-docs, research faculty and/or other participating faculty. There are more non-core researchers working under the LeTUS umbrella at Northwestern than at hi-ce and some of these were more tenuously connected to the work. Indeed related, but distinct projects (for example, projects exploring ideas related to technology-supported inquiry methods in high schools) were also seen as loosely connected to the LeTUS umbrella. Both the researchers and their graduate students described their collaboration as a loose federation of related projects. This structure was an intentional choice, as each of the projects joining the work wanted to maintain their individual identities. The division of labor within the team was not along the line of roles or particular expertise as it was for the hi-ce team. Instead, it was tied to particular funding streams and associated research agendas of the individual researchers. Many of these funding streams and research agendas began prior to LeTUS and were expanded and deepened through the Center's work. In many cases, this work began with the creation of a work circle that developed curriculum on a particular topic related to that research agenda. Each project team then took care of curriculum, professional development, and research design related to their topic.

In addition to the core and associated faculty, both teams used a combination of graduate students, professionals (including post-docs and research faculty), and administrative staff to support their work. The hi-ce team tended to rely on graduate students for the bulk of their labor force, while the Northwestern team found that a few key long-term professionals were critical. The hi-ce team has hired post-docs along the way, but most are around only for a year or two. This difference in labor structure seems tied to both the graduate student supply and the way each team is organized.

There are 18 different graduate programs at the School of Education at University of Michigan, 13 of which offer Ph.D.s. There were usually about 15 graduate students working with LeTUS in any given year, and another 13 working for other hi-ce related projects. Most of these were Ph.D. students and came mainly from three graduate programs: (1) science education (2) learning technology and (3) the combined program in education and psychology, with the largest proportion coming from science education and the fewest from education and psychology. LeTUS/hi-ce employs a small number of the graduate students in education at large, but a large portion of those in science education or learning technologies. Because the faculty is a good-sized one, there is a wide variety of courses available to students including a number of rigorous courses in both qualitative and quantitative methods. This large pool of well trained graduate students makes it possible for them to be regularly in classrooms to conduct observations, interview teachers and students, and support teacher work. Moreover, many of the LeTUS graduate students have backgrounds in science and/or science education, which provided legitimacy for their presence in Detroit classrooms as observers and providers of feedback and assistance.

The Northwestern research team had fewer graduate students available to them than the hi-ce team at University of Michigan, which meant they had a smaller labor pool overall to apply to the work. Northwestern has just two Ph.D. programs — one in the Learning Sciences and one in Human Development and Social Policy. In any given year, about five graduate students were working on LeTUS. The faculty pulled nearly all their students from the Learning Sciences program, which admits approximately six or seven Ph.D. and between five and eight Masters students each year. The program is a broad one and so students come from a range of backgrounds. Not all will be interested in issues related to educational reform in science. With this tight labor supply, the researchers at Northwestern felt particularly challenged to balance the development, service, and research aspects of their work.

As a result, over the course of the LeTUS grant, they came to rely more on research faculty. "The school [SESP] has learned over time that you can't just have faculty with the traditional faculty responsibilities and graduate students and expect to get this kind of work done. There is definitely a need for a group of people who are a part of the organization and are valued for their contributions but do research and development largely" (Northwestern researchers focus group, June 18, 2004). For example, they hired Phillip Herman two years into the grant to help coordinate their site-wide efforts at research. They have also hired professionals to help with the service side of the organization. For example, Lou-Ellen Finn was hired as director of professional development for the Chicago branch of LeTUS.

The time of these professionals is not split in as many directions as that of faculty or graduate students, giving them greater capacity to build and support LeTUS's infrastructure. Those whose duties spanned the various projects within the LeTUS research federation at Northwestern helped create an intellectual core or glue. Moreover, they formed a critical component of the institutional memory, particularly as it relates to research, for the Northwestern team.

Institutional support

In general, there seems to be a fairly good match between LeTUS and the schools of education which house it. Dean Wixson says their efforts align well with the mission of the School of Education at University of Michigan, "hi-ce/LeTUS is a prototype for what I would like all our projects to be like…It really capitalizes on the synergy across research, teaching and service" (Dean Wixson interview, June 22, 2004). She points out the importance of the first that the design and service aspects of the Center emanate from their research questions. As a result, the focus on research within the work is strong, giving it legitimacy within the academy.

SOE is a medium sized faculty with a fairly traditional structure and range of research interests. The 65 professors are divided into two major academic units which are further divided into sub-units. However, "the boundaries across these units are very permeable and so faculty and students often times have multiple affiliations" (Dean Wixson interview, June 22, 2004). As a result, interdisciplinary work such as LeTUS can find a relatively easy home at SOE and the hi-ce team feels largely supported by their fellow faculty members. That said, there are a few scholars at the School of Education who "have been major figures in trying to reestablish rigor in educational research," that is, quantitative studies with hard inferences from population to sample statistics (Marx interview, October 1, 2004). Working in this kind of institutional environment was fine for the efforts of the senior faculty involved in LeTUS. However, it posed some challenges for the participating junior faculty who were using non-traditional methods.

The hi-ce team did experience some minor institutional tension around the maintenance of their financial infrastructure. University of Michigan as a whole has a strong administrative structure for supporting large and complex grants such as LeTUS. However, LeTUS attracted much additional funding, each source of which might have different stipulations for its use. Tracking each source of funds and its allowable uses became increasingly complex. Thus the team found it important to hire hi-ce accounting staff to track all the related grants (and subcontracts to and from the Detroit Public Schools) and assure compliance with the university's accounting procedures.

The LeTUS agenda also fit fairly well at Northwestern University's School of Education and Social Policy (SESP). While expressing some concern about the time and attention the service portion required and its impact on their research, Dean Peterson was supportive of LeTUS. She noted that it was a good match for the school's mission of improving learning and development across the life span, both in and out of schools. Moreover, its focus on research melded with development made it appropriate work for an academic institution (Dean Peterson interview, July 20, 2004).

With just twenty-three professors, SESP's faculty is smaller than SOE's and it is not departmentalized. Instead, it is loosely organized around the two rather unique interdisciplinary Ph.D. programs offered by SESP – (1) Learning Sciences and (2) Human Develoment and Social Policy. There is a strong sense of respect between the faculty associated with each of these two programs. There is also some healthy debate about methods, particularly with respect to those employed by Learning Sciences Ph.D. students in their dissertations.

The Learning Sciences program was the first of its kind and just five years old at the time LeTUS began. The faculty members were still working out the kinks in the program, especially with respect to methods instruction. Many of the Learning Sciences faculty members do design-based research. In fact, it is one of the core institutions associated with the development of the tradition. Since the range of research tools used in design-based research is quite wide, coming up with an appropriate model of methods training has been challenging. Thus, while there has been some debate about the topic, it has largely been around the best way to support the growth of new scholars in a tradition many at the institution feel is a worthwhile one.

The one institutional challenge that concerned the LeTUS researchers at Northwestern was that of continuity. They believed their work to be important, but the need to constantly write grants to finance that work put a drain on their ability to both develop innovations and do research on them. They hired full-time researchers and professionals to support the work and were loath to let that infrastructure go. This meant the lead faculty were constantly chasing money to support the infrastructure.

> It's a huge drain on the PI's [principle investigators]. A very large percent of the amount of time that we've been in meetings together, say in the last year, has been specifically over the issues of "How do we fund and maintain our infrastructure?" So, there's time when Louis [Gomez], Brian [Reiser], and Danny [Edelson] are all in the same room and then it almost always goes to concern over maintaining funding for the infrastructure (Northwestern researchers focus group, June 18, 2004).

Moreover, the full-time, non-tenure track researchers feel a need for a career path. Peterson notes that Northwestern University does have provisions within its structure for the promotion of research staff. As SESP is collecting more employees that fit this category, she is investigating models at other universities for making those promotion decisions.

In sum, the work of LeTUS fits largely within the mission of both schools of education and is relatively well supported by the infrastructure of those institutions. Their work is generally respected by their colleagues, though their methods on occasion are questioned, particularly when it comes to the work of young researchers. The ephemeral and complex nature of the funding which supports the Center creates a drain on researchers' time and makes navigating university accounting systems challenging. Nonetheless, thus far, they have been able to manage those complexities and keep their operations going.

Coordination within each team

LeTUS was a large enterprise and required a good deal of coordination at both sites. Because they organized their work so differently, the kind of coordination required and the challenges each group faced also differed. In particular, the team at University of Michigan was successful at mounting site-wide research and development endeavors, but sometimes faced challenges coordinating the various subtasks — e.g. curriculum development and professional development. At Northwestern, on the other hand, the various subtasks related to a particular curricular unit were generally well coordinated, but they had difficulty mounting a site-wide research agenda.

The hi-ce team had been coordinating work together for more than a decade, but the scale and complexity of LeTUS vastly increased both the range and amount of their efforts. On a day-to-day basis the work was largely accomplished through sub-project teams working on each of the core tasks and/or sub-grants related to LeTUS. The various researchers found they needed to dig deep into their specialty areas in order to get anything done. It was not possible for each of the five core researchers to sit in on all the meetings related to each of these sub-projects, so the team members each became entrenched in their own piece of the work. Marx was the exception.

Marx is a full professor who is well published and respected and has been extremely successful at receiving grants to maintain his research endeavors. His career has been long and his research experience and interests are wide. Moreover, he is a warm and friendly man, with strong interpersonal skills, experience running an academic department, and a genuine interest in the development of young scholars. Thus, in addition to supervising their quantitative data collection and analysis, Marx became the glue that held the team together. He sat in on most of the various sub-project meetings and made sure that each arm of the endeavor knew what the other was doing. He also coordinated with Gray and the other co-directors on the general direction of the Center.

When Marx left Michigan at the end of the LeTUS grant to become Dean of the University of Arizona College of Education, the coordination work became harder to manage. The members of hi-ce genuinely like and respect one another, so these were not deep personal frictions, but rather problems of work flow. “It wasn’t that people weren’t in tune to the consensus and trying to carry out what we had agreed to, but as things came up and as the decisions started to be made to solve problems, those decisions weren’t always coordinated” (University of Michigan researchers focus group, June 14, 2004). The team members needed to find a mechanism for keeping up with what each other was doing. Currently, they are doing so through a combination of periodic management meetings, more explicit conversation between the two development arms — curriculum development and professional development — and the hiring of more personnel to work on details in order to free up the lead researchers’ time to coordinate with one another. This personnel includes graduate students, post-docs, and administrative staff who take over pieces of research and development, track and coordinate the data collection process, oversee budgets, etc. However, the 2003-2004 school year was a major transition period for the team, both because of Marx’s departure and the beginning of new research and development which emerged from the now completed LeTUS grant. Indications in

June of 2004 were that the group was still working through the process of refining a coordination mechanism that would suit their needs.

The Northwestern University team did not have a person to help coordinate LeTUS activities in the way Marx did for hi-ce. Rather, Gomez, Reiser, and Edelson together coordinated the activities for the group when necessary, but the bulk of the work was done within the individual project teams. As a result, all three of these researchers were also juggling their own projects within the LeTUS umbrella as well as managing the umbrella itself. While all three were involved in coordinating with district leaders and teachers to some extent, Gomez was the lead contact for both principals and district leadership. In addition, he provided a public face for LeTUS and served as the main liaison between LeTUS and funders and policy makers in Washington D.C., a job that took him away from the day-to-day work to some extent. "Part of what I learned is that … projects like these need public faces and they need internal managers and you can't do both" (Gomez interview, June 18, 2004).

This organizational structure created a research context that was highly productive for the individual project teams, but it made site-wide research somewhat difficult. As one Northwestern researcher explained, "We created the center at the idea level; that is, we had and have people who have a common vision about how work should be done. … The data collected around it [the vision] was sort of more personal and individual than it was organization-wide" (Northwestern researchers focus group, June 18, 2004). As a result, each sub-project within LeTUS was fairly well coordinated — researchers and graduate students in charge of particular work circles coordinated curriculum development, professional development, and research on the topics covered by the unit in question. However, a research plan that would span efforts in Chicago, such as investigations into the effects on student learning or teaching practice throughout all the classrooms involved in LeTUS, was difficult to mount, particularly with their relatively small labor force. "Collecting data, even in the most basic way, that spanned the project was really, really hard. Even simple logistics of getting pre- and posttests from everybody was almost the limit of what we could do" (Northwestern researchers focus group, June 18, 2004).

Coordination across research sites

The two research and design teams generally worked separately but tried to inform one another intellectually, through a number of avenues including periodic meetings, writing papers and grants together, and sitting on dissertation committees for students at one another's institutions. The very different working structures of both districts and research teams made this a reasonable working procedure, though it was not always easy to keep one another well informed. The researchers interviewed noted a sense of missed opportunity in some cases.

For example, it might have been nice to be able to either compare or collate results from pre- and posttest data in the two sites. These instruments were tied to the curricula and the curricula were quite different in each site. Thus it would not be possible for them to be exactly the same. The researchers could, however, have explored some kind of parallel construction. This did not happen. The hi-ce group was able to start collecting pre- and posttest data from the first year of the work. This effort was assisted by the fact that they had received a grant for creating assessments of student learning at the same time they received the LeTUS grant. However, the Northwestern team's work on the pre and posttest measures did not gain full steam until Herman joined the team as research faculty two years into the work. Once there, Herman was constantly playing catch-up with his colleagues at University of Michigan. "Every time I would see Phil [Herman], he would say, 'I'm doing this kind of analysis,' and I would say, 'Yeah, we did that last year,'" (Marx interview, October 1, 2004). By the time Northwestern's instruments were developed, the hi-ce group had already moved ahead with their own research plan and it would have been difficult to coordinate them. The researchers learned from this experience and in their continuing post-LeTUS work together, they have created mechanisms for piloting curriculum and measures of student learning in both sites.

Contributions and publications

The main grant for the LeTUS center was received in 1997, but it was not until 2002 that the first papers demonstrating the impact of the work on student learning began to be published in journals. This time lag is not uncommon in design-based research where five to seven years can pass between when the research begins and solid findings of the effects on student learning are available. Both the time to build the research context, as well as the need to balance service with research are significant factors in the typical publication delay. Other factors in the case of LeTUS included the organizational procedures each site used for publication and the extent to which they felt they knew *how* to write about their findings.

The hi-ce team at University of Michigan had a long-standing practice of submitting at least one article a year for peer review in a journal about their collective work. They were always co-authored, generally by all of the core faculty involved in hi-ce, and tended to focus on broad findings and big ideas generated from the work. Blumenfeld was the driver of this activity and she took it as her mission to ensure they kept publishing regardless of other distractions. They continued this practice throughout LeTUS.

The Northwestern team did not have a similar routine in place. In addition, since they didn't have as large a site-wide corpus of data as did the hi-ce researchers, they had fewer empirical findings to write about that spanned their collective work. Thus most of their writing and publication came from the work of the individual projects within the federation and their graduate students. "When we would try to take stock of what we've learned, it's often a collection of dissertations. … Many of them are good or excellent pieces of work, but they don't have a kind of overarching coherence" (Northwestern researchers focus group, June 18, 2004). Moreover, currently they do not have a comprehensive understanding of the effects of LeTUS on student learning. Complications accessing achievement data, difficulty collecting cross-site data, and the interests and organizational structure of the team, all presented challenges to producing such findings. In today's policy context, research is likely to be considered incomplete until evidence of student learning is provided, particularly evidence with respect to student achievement on politically important tests. Thus, at the moment, the Northwestern team is limited in their capacity for making convincing arguments that LeTUS "works" in Chicago schools. However, the grant has just finished and data analysis and writing from their work are not yet complete. Given the typical time it takes to process and report upon design-based research, it is a bit early to be judging what their final contributions will be.

The LeTUS researchers find they are still looking for the proper way to express some of their insights from this work. While it is always challenging to marshal the time to reflect upon and write about their work, they might find such time more readily if they knew how they wanted to go about that writing. "A lot of the stuff we do, I find difficult because I don't know how to think about it as a product of scholarship to be honest with you. … I can marshal my efforts to do the things I know how to do. I know how to write grant proposals, so I write them and I don't know how to write up the results of an improvement project, so I don't" (Northwestern researchers focus group, June 18, 2004).

Despite these challenges, the LeTUS researchers collectively produced a number of graduate theses, research reports, conference papers and publications based upon their work. They have made contributions to the learning sciences literature (e.g., Quintana et al., 2004; Reiser, 2004), the science education literature (e.g., Edelson, 2001; Schneider, Krajcik & Blumenfeld, 2005), the teacher education literature related to professional development (Fishman et al., 2003, March; Schneider & Krajcik, 2002; Shrader & Gomez, 1999), and the literature on literacy in the content areas (e.g. Moje et al., 2004). However, they believe their most significant contributions have been to the knowledge base about systemic reform in science education, particularly for urban districts (e.g., Blumenfeld et al, 2000; Marx et al., 2004).

They have amassed and reported on a large amount of data related to LeTUS's efforts at systemic reform. One University of Michigan researcher noted, "I think we probably have the most data of all of the Urban Systemic Reform efforts" (University of Michigan researchers focus group, June 14, 2004). A critical part of this research was investigating the connections between the various aspects of the LeTUS enterprise. While each individual component might not have been novel on its own, the collaborators believed their synergy was, and they have worked hard to understand the links between them. For example, one researcher said of a paper on professional development in LeTUS (Fishman et al., 2003),

> We made an argument for the importance of justifying professional development with student outcome data and informing design of professional development with student outcome data as the test of whether it was working or not and developed a method of tying together many different elements that begin with teacher belief and knowledge and go through classroom practice and end up with student performance. None of which are novel things to look at, but it was novel to try to look at them all in the same study (University of Michigan researchers focus group, June 14, 2004).

In addition to their scholarly findings on systemic reform in science, they have contributed significant practical knowledge to the field. They have studied best practices among LeTUS teachers. Gray has given talks at numerous other districts about the science reform efforts in Detroit. LeTUS as a model of partnership is part of her spoken message. Moreover, in addition to the curricula materials themselves, they have created models for producing both materials and professional development that will effectively support systemic reform in science.

> I think the most interesting thing from a knowledge standpoint is where we are today compared to where we were six years ago. … I think that we could really go to any district and give them a strong argument about professional development and how it has to be rooted in what the teachers are going to do in the classroom and Barry [Fishman] could give a really articulate model where I think six years ago, we could not have given that story. The other story I think that we can give very convincingly that actually stemmed out of LeTUS is how to design materials so that they can really help a variety of all kids learn (University of Michigan researchers focus group, June 14, 2004).

They are quick to point out that in their work the theoretical and practical are closely linked. Each model they have is backed by a real system or artifact in place that embodies the model. The use of that system or artifact in turn informs the development and refinement of the model. Thus the learning technologies and curricula they produce embody their models for inquiry-based teaching and learning and curriculum design. Likewise, they have developed on-line professional development systems, *Knowledge Networks on the Web* (KNOW), and the *Living Curriculum* that at least partially embody their model for professional development (Fishman, 2003; Shrader & Gomez, 1999). And their methodological contributions to scaling design-based research (Fishman et al., 2004) are embodied in the Center itself.

Development of young scholars

Involvement in LeTUS was a double-edged sword for most of the young scholars interviewed. The work was exciting and the training experiences were broad. The graduate students were well supplied with the tools of research (computers, video recorders, etc.), had spaces in which to work and ready-made colleagues involved in similar activities. They note that their involvement in LeTUS greatly facilitated their access to sites for their thesis-related research. Teachers and principals involved in the Center were very welcoming of graduate student research related, even if tangentially so, to the LeTUS agenda. The hi-ce graduate students felt particularly fortunate because they had a large and cohesive set of fellow graduate students with whom to share thoughts and ideas. The Northwestern students tended to feel more connected to their individual projects than to LeTUS as a whole, though they still saw the Center as a source of both resources and colleagues. Many at both sites were already published or at the very least had presented at several conferences before completing their dissertations.

At the same time, the work load was phenomenal. Balancing their time between the design, support, and research aspects of the work was challenging. In addition, they had to balance their time between research needed for the sub-project of the center to which they were most closely connected and their own thesis work. This kind of challenge is one typically faced by graduate students on design-based research projects. However, the added layer of site-wide research made it more complex.

Graduate students at Northwestern said they were generally very busy until their last year, at which time their supervisors required little of them as they worked hard to complete their theses. Several described needing to physically remove themselves from the beehive of LeTUS activity in order to begin doing the thoughtful reflection necessary to complete a thesis. The hi-ce students noted their chief difficulties came when the different arms of the LeTUS team at Michigan didn't coordinate well enough. In at least one case, this led to an untenable data collection load for some portion of the students. On the whole, however, they seemed happy to have been part of the effort.

In addition, like all young scholars, they faced the challenge of crafting a *doable*, *rigorous,* and *unique* program of research for their dissertations. The complexity of design-based research—its collaborative nature, the wide range of methods used, and the voluminous data often collected—adds additional challenge to this task. Does each student do a mini design-based research project (with all the pieces at a smaller scale) within the context of LeTUS? Or do they carve out a bit of the LeTUS wide research to call their own? If the latter, what kind of piece can be carved out of this rather large and complex endeavor that is meaningful on its own? Or as Marx put it, the students needed to learn the art of parsing practice into studies, "But it's a real struggle for novices to figure out how to do that" (Marx interview, October 1, 2004). Dean Peterson noted that at Northwestern, she saw this problem play out as a kind of tension between the implementation and research aspects of the work. "A lot of what they were doing in LeTUS was implementation. It was designing curriculum and implementing it, right? Then looking to see what happened, which is tricky to do even as a sophisticated researcher to get a good, rigorous study out of that. I think as novice researchers, that's even harder" (Dean Peterson interview, July 20, 2004).

The faculty involved in LeTUS recognized these challenges and did their best to help students navigate them. They believe one of their important contributions to the field is the training of scholars who can engage in design-based research like LeTUS. The best way to train design-based researchers, however, is an interesting open question. Effective design-based research requires a wide range of skills: proficiency in the design and development of innovations, the ability to work closely and respectfully with educators, the ability to coordinate your work with others in a research team, skill at tracking, coordinating, and sifting through a huge corpus of data, and a plethora of qualitative and quantitative research methods. Most experienced researchers who do design-based research were trained in a discipline (e.g. educational psychology) and added to their research repertoire over time. Thus they have deep knowledge of at least one discipline that informs the enterprise.

In contrast, most graduate students, post-docs, and young faculty brought up in this tradition are hybrids, one generation removed from the core disciplines which inform design-based research. As is the case in any developing interdisciplinary tradition, these young scholars face both the challenges and advantages of interdisciplinary training. They may have some training in a wide range of design-based research related methods and theory, but they may not have either deep or intensive training in any one of these traditions. Broad exposure may help them understand and be able to capitalize upon the synergies between the different aspects of the work. But it may also hamper their ability to either approach the work with serious rigor and/or present their work in ways that are recognized as either rigorous or belonging to what others see as a scholarly home. Moreover, design-based research tends to be highly collaborative, which may make it challenging for some young scholars to demonstrate their unique contributions to the field.

For example, Barry Fishman was a member of the first cohort of the Learning Sciences program at Northwestern University. He did his Ph.D. work and a two year post-doc as part of the CoVis project and then obtained a faculty position in the Learning Technologies program at the School of Education at University of Michigan. Thus his entire early training and career have been in a design-based research context working with teams of collaborators. Moreover, his graduate training at Northwestern occurred at a time when the structure of the program was still evolving and course work on methods was nascent. Students sometimes sought supplemental course work outside the program, however, most students at that time picked up the bulk of their methods training through their apprenticeships on research projects with faculty.

In 2003-2004 Fishman became one of the first graduates of the program to come up for tenure. His curriculum vitae is long and impressive. There are numerous journal publications, conference papers, and invited presentations. He has an active program of funded research and is involved in the scholarly community through participation in professional organizations, committees and editorial boards. Despite this strong line of work, his tenure bid was a challenging one. He was ultimately successful, but the challenges he faced are emblematic of those likely to be encountered by other design-based researchers seeking tenure.

In some ways, participating in LeTUS was a boon for Fishman. He was able to work in a research context that he could not possibly have created all on his own and explore questions that were not possible without that context. His close collaboration with the other members of the team bolstered both his publication and grant award rates and provided a deep form of mentoring and apprenticeship. On the other hand, Fishman had been cautioned throughout his probationary period by his dean, department chair, and colleagues that in order to ensure tenure, he should make certain that his work

- Had a recognizable disciplinary home;
- Contained recognizably empirical work (that is, with clearly articulated hypotheses and findings), and;
- Included a number of single-authored publications.

Working on LeTUS would make all three of these tasks difficult (Fishman phone conversation, January 11, 2005). The work was decidedly interdisciplinary and linked to a field (learning sciences) about which some of his colleagues were uncertain. Indeed, Dean Wixson reported that there were a number of conversations in the faculty around the topic. "What are the learning sciences? What are design experiments? Is this just a fad or is this the future of educational psychology?" (Dean Wixson interview, June 22, 2004). The time it takes to establish the context for research and the breadth of data collection meant that the *recognizably* empirical work – that is, work that looks like traditional studies or evaluation efforts that capture impact on teacher practice and student learning – could take several years to accomplish and would be difficult to complete before he had submitted his tenure application. This challenge in addition to the workload inherent in participation in the design, implementation and support aspects of LeTUS, would make speedy and voluminous publication difficult. Finally, because he was working as part of a team and much of their work was done collaboratively, their publications were largely co-authored. Fishman could have made his life easier by deciding to work on a small scale study on his own with a couple of graduate students. But, he felt the work of LeTUS was both interesting and important and so became involved knowing the risks it would create for his tenure case.

Marx believes that Fishman's tenure case was made more difficult by the current push for "scientific" (i.e. quantitative, controlled, experimental) evidence in educational research. Fishman had traditional empirical work among his accomplishments. However, his portfolio featured co-authored and design-based work prominently. Both Dean Peterson and Dean Wixson worried about the ability of researchers trained like Fishman to build their own research agenda. Peterson noted that it was difficult to distinguish Fishman's contributions from those of some of his colleagues in hi-ce. And, indeed, most of his papers and publications are co-authored. Likewise, Wixson commented that researchers like Fishman would always need to partner with others since it was not possible to have all the expertise necessary to do the work they wished to do. These attributes combined with the current push for "scientific" evidence and the somewhat traditional outlook of SOE made his tenure case challenging.

In today's high accountability environment, it would serve young design-based researchers well to become capable of doing experimental and quasi experimental research (Marx interview, October 1, 2004). In the end, everyone is going to want them to make causal inferences about the innovations they bring to bear on the problems of education. The comments of the two deans demonstrate a particularly thorny challenge. Gaining tenure is still largely an act of proving one's own individual contributions and worth to the scholarly community. No one is in the least bit troubled by the fact that Blumenfeld, Krajcik, Marx and Soloway receive most of their grants and do much of their writing together. Which of them made what part of their collective contribution to the field is not questioned. However, those questions will be asked of young scholars. Until such time as they have gained tenure, young faculty doing design-based research will either need to do it on a smaller scale than LeTUS or be very careful about how they position themselves within a larger collaboration.

Summary and implications

Design-based research is generally a complex activity, involving a wide-range of methods, large amounts of data, and the coordination of the efforts of many people. LeTUS was no exception. In fact, scaling the work to involve not only more classrooms, but district contexts and practices added another layer of complexity to the work. The resulting range of changes made to the teaching and learning activities in classrooms and the practices of each district were numerous. The extent and effects of all these changes could not be studied in detail, and so choices were made at each research site as to the questions to pursue and the way to best organize the work to pursue them. Some of these choices were based on the research expertise, experience, interest, and preferences in each group. Some were influenced by the needs and structure of each district. As always in design-based research, some were based on questions that emerged as the design itself evolved, such as the close attention that was paid to the evolution of professional development in Detroit. Still others, particularly toward the end of the grant, were influenced by the policy context with respect to educational research.

There are some interesting parallels between the structure and needs of each district and the structure and interests of each research institution. It just so happens that the more centralized district (Detroit) was paired with the more centrally organized research group (hi-ce), while the decentralized district (Chicago) was paired with a research team organized as a federation (Northwestern). Likewise, the district with the most interest in findings related to state tests in science (Detroit) was paired with the research team that early on had both expertise and interest in exploring the effects of their work on such tests (hi-ce). It is thus a bit difficult to disassociate the effects of each district's needs and structure on each research team's choices from the serendipitous confluence of these pairings. Each pairing worked well together, but they do call into question whether they would have been as productive if they had been reversed, a question to bear in mind if and when others wish to construct similar relationships.

It is important to note that both research teams faced challenges coordinating the work. It is simply not possible to have so many people working together on such a complex set of problems without running into issues of coordination. The organizational structure each team put into place had implications for the *kind* of coordination challenges they faced, but did not change the fact that they faced them. Because of these coordination challenges, work of this kind is easier if the participants like and respect each other.

Creating the research context for LeTUS was an enormous endeavor and the teams would like to maintain it. Doing so is a bit challenging within an academic context. Research grants are generally short-term forms of funding and so maintaining both the research infrastructure and the relationships with the districts requires that significant effort go into writing and obtaining grants. Thus far, the researchers have been able to amass the funds they need to continue the work in productive ways. What the eventual limitations might be for efforts of this kind within an academic context are not yet clear.

Finally, while both the definition and worth of design-based research is still under debate in the field at large, each research team found their work to be largely respected by their colleagues. Some of their methods were called into question, particularly given the current national focus on traditional forms of research. Moreover, the time it takes to publish their work was sometimes a frustration. These concerns had a larger effect on the young scholars involved in the work, that is, graduate students proposing and defending theses and faculty applying for tenure. That said, there were three faculty members working on LeTUS across the two sites who applied for tenure while the Center was active and all three were successful. Likewise, several students successfully defended theses. However, it is possible that design-based research of this scale is not feasible unless tenured faculty, who have more freedom with respect to their work and can afford to take more time with their publications, are involved and supporting the management aspects of the effort, giving their students and less experienced colleagues the support they need to succeed. In the end, the researchers continued to receive funds to extend the work begun in LeTUS. Thus, while methods and publishing rate were issues to be considered and managed, they were not roadblocks to success.

BEYOND LETUS: CONTINUING COLLABORATION AND ATTEMPTS AT FULLER SCALE

Scale is generally considered in one of three ways: take on more classrooms; take on entire school or district systems; or extend the innovation to cover more subject matter. The nature of the early pre-LeTUS work of many of the researchers focused on very specific curricular topics. With the exception of CoVis, they also mainly worked with a relatively small number of teachers.[21] Although CoVis scaled to many classrooms, the researchers never really grappled with the problem of implementing reform throughout a school or district. The hi-ce group had some fledgling experience in building close working relationships with schools during its *Community Science Connections* project, but they had not yet tackled an entire district system.

LeTUS attacked the issue of scale on all three of these fronts, but in a modest way. The project took on two districts and *only* two districts, and allowed each university team to focus on just one of them. They expanded their curricular repertoire, but did not endeavor to create a *complete* middle school curriculum. Moreover, their strategy of creating replacement units enabled them to work with a slowly increasing pool of largely *willing* teachers within each district. Thus they were able to scale to many more classrooms and build overall district capacity without tackling the problem of teachers who are truly uninterested in or resistant to change. These modest attempts at scale enabled them to learn about the infrastructure supports necessary to facilitate their curricular and technological innovations without greatly overtaxing their own ability to provide it.

While the initial funding for LeTUS is complete, there are some in the collaboration who do not see LeTUS itself as over. They see continuing work in the districts and continuing collaborations among the four institutions under new funding sources as direct extensions of LeTUS. “I wouldn’t say it’s over (laughs). It is the funding cycle for the National Science Foundation that ends this year [2004]. But the whole idea was to begin to institutionalize those practices so that the work could continue” (Gray interview, June 14, 2004). The units they developed together serve as a vehicle for continuing that work throughout the district.

---

[21] PBS did hold summer institutes toward the end of their grant, each of which involved about 75 teachers across the state, but this was considered a dissemination piece rather than the core of their work.

The researchers and educators involved in LeTUS are extending work in many ways. In one post-LeTUS project, several of them are now attempting to create a full, publishable middle-school curriculum. The core funding for this work is an Instructional Materials Development grant from the National Science Foundation entitled *Investigating and Questioning our World through Science and Technology* (IQWST).[22] The attempt to scale both the comprehensiveness of and the audience for their curricular designs has led to several shifts in the working procedures for the collaborators. Individuals from all four institutions are still involved, but the shape of their interactions has changed somewhat. In particular, the lion's share of the curriculum design is now done by the researchers. The design process itself has become much more refined and is based upon an assessment-driven model of design (Wiggins & Tighe, 1998). Explicit consideration of content knowledge in science has taken center stage, and the integration of technology has become a background piece. Finally, the intent of problematizing the district's work in order to catalyze change is less of an issue in this new endeavor.

Shift in the role of content knowledge

"When we started LeTUS and the units were meant as a vehicle to get something different happening in classrooms, we adopted a replacement unit approach. It was fine to spend six weeks on something like ReNUE even if the learning goals were pretty nebulous" (Reiser email message, November 18, 2004). This strategy allowed the researchers to jump-start their design work with curriculum seeds already in existence. Moreover, since their *original* goal was the integration of technology, it allowed them to create units focused on the kind of inquiry learning they had software tools to support. However, this strategy had several limitations.

First, the difficulty they had establishing a technological infrastructure meant that many teachers did not have sufficiently reliable access to the software tools, making their use as a centerpiece for a unit questionable. Second, a replacement unit strategy can lead to many teachers adopting just one unit. While units were chosen with district needs in mind, they did not in any way "cover" the territory of learning to which the teachers were beholden. As such, they were limited in their ability to support comprehensive systemic reform. Finally, to imagine that a single three-to-ten week unit within the span of a student's entire twelve year career would have an enduring impact on either student learning or classroom activity is unrealistic (Reiser phone conversation, December 6, 2004). In order for the curriculum to be tenable as a lever for systemic reform or to have a sustaining impact on teaching and learning, it needed to be more comprehensive. And, in becoming comprehensive, the LeTUS (now IQWST) team had to take on certain moral and political imperatives.

In the pre-LeTUS days, the researchers and their teacher collaborators were generally attempting to simply engage students in the activities of inquiry: developing questions, collecting data, analyzing and modeling, crafting explanations, and so on. Tools and supports for helping students engage in these activities were often specific to particular natural phenomena.

---

[22] For more details on the IQWST project see: www.hi-ce.org/IQWST.

For example, Reiser's BGuILE group built a learning environment that gave students access to a large dataset related to finches on the Galapagos islands. This dataset is particularly useful for demonstrating the relationship between trait variation and survival in a species. What the research group cared about *primarily* at the time they built the software was creating opportunities for students to create scientific explanations. Their research focused on the quality of those explanations and the ability of the software to support them (Sandoval, 2004; Tabak, 2003). That the explanations students created were about the differential survival of finches under environmental stress was a secondary consideration. The finch scenario was chosen because the data were available and an argument could be made that it met some portion of the science standards. Since the unit only took about three weeks of classroom time, it could be easily argued that teaching students to produce strong scientific explanations was in and of itself a reasonable goal.

This argument does not hold when one is creating a comprehensive curriculum. In their post-LeTUS work, the IQWST team no longer has the luxury of being cavalier about what science content their designs address. In the face of district needs and state testing, the specific concepts to be learned now receive as much attention as engagement in scientific reasoning and inquiry. "In our current, IQWST work, we can't get away with that. We need to figure out how to treat the content goals that teachers expect to reach in a typical year, and do it in a way that realizes our pedagogical goals of making science meaningful and involving students in inquiry" (Reiser, email message, November 18, 2004).

Inquiry-based curricula engage students and teachers in deep exploration of the concepts and phenomena involved in the investigation. As a result, the curriculum designers themselves need a deep knowledge of that content. This knowledge entered both the LeTUS and IQWST design teams in a number of ways. In some cases it was part of the knowledge base researchers involved in the work already had, or they were able to study the subject in sufficient depth to support the curriculum design. In other cases they hired post-docs or graduate students with science background in the subjects and/or phenomena involved in the curricula. And finally, in some cases they partnered with experts from other organizations (e.g. the Brookfield Zoo) to pull in the knowledge needed. All three of these methods served to improve the knowledge base of the design teams as a whole and in the case of LeTUS enabled them to pass that knowledge on to the teachers via the curriculum and/or professional development.

Finally, the technology integration has been pushed to the background and plays a subservient role to content. While lessons that incorporate technology are still included, the IQWST team makes certain the units are structured such that the core concepts can be learned even if access to technology is either limited or non-existent. This new focus on scientific content has, in turn, led to a shift in the design process.

Shift in design process

The IQWST team uses a much more sophisticated model of curriculum development than they did during their LeTUS work. Based on what they learned from

LeTUS, they created a detailed list of core design principles for high quality inquiry-based curricula. These principles in conjunction with a process of *assessment-driven design* are used to build their new curricula (Reiser, Krajcik, Moje & Marx, 2003). In their assessment-driven design process, they begin by selecting a cluster of standards from national standards (AAAS, 1993; AAAS, 2001; NRC, 1996) all related to a big idea. They elaborate and clarify the standards related to that big idea and describe the learning performances they would expect students to exhibit for each standard. For example, "Students identify and represent mathematically the variation on a trait in a population" (Reiser, Krajkic, Moje & Marx, 2003, p. 10) is a learning performance related to standard 5F2-I from *Benchmarks for Science Literacy*, "Differential survival: Individual organisms with certain traits are more likely than others to survive and have offspring" (AAAS, 1993, p. 124), which is related to the big idea of "ecosystems." Once these performances are outlined, they create assessments, tasks, and activities that would enable students to demonstrate them. These are put together in a coherent unit focused with a driving question rooted in the big idea.[23]

The IQWST work is being done in two phases. In the first phase, the team developed two units to test the design process itself — one built at Northwestern and the other at University of Michigan. With these first two units they had some latitude over the content they would choose to work with initially. The hi-ce team chose to create a brand new unit. The Northwestern team, however, built an ecosystems unit based upon a LeTUS unit called *Struggle for Survival*. They chose to do so in order to leverage their piloting work with their knowledge related to that topic, such as content knowledge and knowledge about how students learn that content.

Now that the pilot phase is complete, they are working completely top down from standards. They no longer start with curriculum seeds, such as the Finch dataset. When they do know of tools/datasets that might fit with those standards, they will consider using them. However, they no longer pick topics to suit the tools and their own knowledge base. Instead, tools will be chosen to fit the topics and their knowledge base will need to be built where necessary.

Shift in the collaboration

In LeTUS most of the curriculum development was done to meet local needs, and there was very little design work across that divide. "For a while we lost communication with Northwestern so they went about their curriculum design efforts and we went about our own curriculum design efforts and we didn't really inform each other as much as we could have" (University of Michigan researchers focus group, June 14, 2004). They still do the main development work at one site or the other, but there is much more cross-fertilization. "One of the things that fostered that cross-fertilization is that the curriculum, as soon as it's designed, it gets piloted and enacted in both sites" (University of Michigan researchers focus group, June 14, 2004). As a result, the university level collaboration is

[23] This is a *highly* summarized description of the IQWST curriculum design process. Interested readers should see Reiser, Krajcik, Moje & Marx, 2003, for more details.

much more intense than it was during LeTUS. Reiser and Krajcik, in particular, video conference with one another several times a week.

Teachers and district leaders still collaborate on the new IQWST work, but in a much different fashion now that the curricular designs are no longer based on district needs, but rather national standards.

> The work circle model was very good for developing curriculum designed for a local audience that the local district felt ownership over. Most important, it was a great PD experience for all involved — teachers, scientists, and LS researchers. However, it's not an efficient mechanism for developing larger curricula for broad dissemination (Edelson email, November 18, 2004).

As a result, they are no longer using work circles at Northwestern University. The work is too detailed and intensive now for them to expect full-time teachers to engage in it. Instead they hire full-time staff members, such as Lou-Ellen Finn, with significant teaching background to help them do development. Full-time teachers aren't brought into the process until IQWST is ready to have the curriculum reviewed and piloted.

In addition, they are also hoping to begin developing materials to support lead teachers doing professional development. The researchers recognize that they cannot always be so deeply involved in the professional development process. "We can't do it. We can't travel all over the country" (University of Michigan researchers focus group, June 14, 2004). They have put in a proposal to the National Science Foundation to explore the possibility of developing such materials.

Post-LeTUS Impact on the Districts

LeTUS initially held the goal of problematizing each district's work, catalyzing both reflection and change with respect to their current organization and practices. The post-LeTUS impact on each district indicates that the Center was successful in this regard. In addition, involvement in the Center has built enduring relationships between the districts and their local university that continues to serve as a source of learning and growth for each.

The hi-ce team continues to work closely with Detroit Public Schools on issues of systemic improvement of science education. In return, the district continues to support and be interested in hi-ce's on-going research and development work in this area. The LeTUS units are still an officially sanctioned alternative to the district-adopted curriculum materials, and the hi-ce research team continues to be involved in supporting the professional development infrastructure for teachers who use those units. Toward the end of the LeTUS grant, Gray asked Krajcik to join a group of district educators who were rewriting the district's curriculum framework for middle school science. In this way, what the Center had learned about inquiry-based science instruction became embodied in the district guidelines for science instruction. Moreover, Gray has used that process as a model for the elementary and high school teams to create similar collaborations with other university partners for the purpose of revising the frameworks at those levels.

Similarly, in Chicago, the effects of LeTUS continue to be seen in the district's work. The Chicago Mathematics and Science Initiative (CM&SI) came into effect in the 2003-2004 school year. Knowledge of and from the LeTUS curriculum and professional development has played a key role in the development of the science component of the initiative. First, as mentioned earlier, much of the leadership for this initiative has ties to LeTUS, including district staff, special coaches and lead teachers in schools. Second, the models of professional development used in LeTUS have informed CM&SI's offerings in professional development.

Third, Lach and his colleagues at the CM&SI consider their Northwestern counterparts to be intellectual partners and call upon them as sounding boards when exploring new plans. For example, recently Lach was working on plans to refurbish their 1950's style science labs throughout the district. He called upon his Northwestern colleagues to help him think about the question, "If we were to design them now for the year 2020, what would they look like?" (Lach interview, October 6, 2004). Moreover, while some of the LeTUS research and design work is not immediately applicable to CM&SI's reform efforts, they find it eventually provides them with useful insights. "The stuff does combine. … We certainly benefit from it, even if the initial audience is AERA people" (Lach interview, October 6, 2004).

Finally, LeTUS has influenced the initiative's curricular decisions. Unlike the previous Chicago Systemic Initiative, the CM&SI is being proactive about curricular recommendations. They have chosen curriculum at the elementary, middle, and high school levels that will be supported by the initiative. While schools may still make their own decisions, they will not receive CM&SI support unless they choose the Initiative's curriculum. That support includes funds for texts and materials as well as professional development.

The district decided *not* to adopt the LeTUS units as official curriculum for the Initiative. Lach said that while the materials are impressive and a model of what science teaching can be, they are neither refined enough nor complete enough for him to use as a tool for supporting a district-wide improvement plan. Nor would it be possible for Northwestern to provide professional development for the materials on the kind of scale a publisher provides. Several of the lead LeTUS teachers interviewed were also serving as lead teachers for CM&SI in their schools. They noted that while they themselves loved the LeTUS materials, they believed those materials would be too challenging for the vast majority of the teachers they are currently supporting, some of whom neither know much about nor are terribly interested in science.

For these reasons, Lach and his team instead used the LeTUS materials to *inform* their choice of middle school science curriculum. In the course of reviewing materials, Lach found his experience working for LeTUS on curriculum design to be invaluable. "Learning this design process and understanding how important all of the thinking about cognition and kids and organizations that goes into these things, I understood that first hand" (Lach interview, October 6, 2004). He and his team then used this knowledge to deliberately pick curriculum that came as close in spirit to the inquiry-based designs of LeTUS as they could and have let LeTUS teachers know that they can continue to use the

LeTUS materials in place of these where appropriate. Moreover, they continue to support Northwestern's IQWST design and research efforts in the district in part because they hope it may lead to a curriculum that *is* a viable tool for supporting systemic reform.

DISCUSSION

The Center for Learning Technologies in Urban Schools demonstrates a number of interesting issues and possibilities for the capacity of design-based research to engender sustainable and scaleable models for improving teaching and learning. First, LeTUS built a successful infrastructure for supporting inquiry-based teaching and learning by drawing upon the expertise of both researchers and educators to inform their designs. Their experience shows that successful use of this broad range of knowledge and expertise is not a simple act of compromise or of informed consent. Rather it requires being cognizant of whose expertise is best for what as well as the ways in which the organization of knowledge and expertise affects the coordination of the work. Second, they scaled their work to affect hundreds of teachers and thousands of students by localizing their designs to the needs of individual districts. There is an obvious question then as to the trade-offs between localization and dissemination of this work. Third, the extent to which one considers design-based research such as LeTUS successful depends on one's definition of the nature of success. Both sites were successful, but in different ways. Together, they show that the strategies used by the Center can be viable under a variety of conditions. Finally, design-based research itself has been criticized as being difficult to scale beyond a few classrooms. The LeTUS experience provides at least one possible pathway for nurturing the work of design-based research beyond these usual limitations. Each of these issues and possibilities is discussed in detail below.

Knowledge and expertise needs in design-based research

Design-based research typically requires a broad knowledge base spread across several individuals. LeTUS was no exception. Researchers brought to the effort knowledge of theories and research related to student learning, knowledge of theory and practice related to inquiry-based science teaching, in-depth science content knowledge, knowledge of research and theories related to professional development, knowledge of research methods for capturing classroom activity, teaching practice, student learning and student and teacher perceptions and motivations, knowledge of technology and its usefulness for teaching and learning, curriculum seeds and ideas, and an extra pair of hands and eyes in the classroom. The educators brought to the effort knowledge of district and school organization, familiarity with school and district policies, initiatives, standards, bureaucracy and politics, knowledge about schools and teachers with the capacity to engage in this work, a capacity for evaluating the efficacy of curriculum and professional development given school and classroom realities, knowledge of typical work flow in classrooms and schools, familiarity with practitioner literature, language, and perspectives, and knowledge of students and their needs. Both researchers and educators either brought or needed to develop knowledge of how to run large organizations, knowledge of how to manage complex budgets within their institutional bureaucracies and knowledge of how to provide a public face for the work.

As the stories of the work in the ReNUE work circle and the evolution of professional development in Detroit clearly show, effective use of this vast array of knowledge and expertise required understanding whose knowledge was strongest in what areas. While some decisions were matters of making compromises between differing perspectives, most were a process of deciding the most *relevant* knowledge for solving a given problem.

Content knowledge played a particularly important role in the Center's work. Conduits for bringing that knowledge into the curriculum design teams and then passing it on to teachers was critical to making instructional improvements in classrooms. As the work is scaled to that of a full middle school curriculum, the focus on content is becoming even more important for reasons of accountability as well as instructional quality. Supports to ensure teachers using the materials acquire such knowledge is likely to be a significant issue in their future designs.

The *organization* of knowledge and expertise within each site also had implications for the work. Detroit and hi-ce functioned in a much more centralized fashion, while Chicago and Northwestern worked in a more distributed fashion. Design-based research as complex as that of LeTUS cannot be conducted without running into coordination challenges of some kind. What LeTUS demonstrates, however, is that the organization of knowledge and expertise within a given design-based team has implications for how those challenges will unfold.

Localization and dissemination

LeTUS employed a client-focused research and development strategy that purposefully shaped its work to the teaching and learning contexts of each district. The close involvement of teachers and district leaders in these efforts led to the successful development of curricula and professional development systems that suited the preferences, capacities, and structures of each district. However, localization of these designs also made them less amenable to use in other contexts and was part of the reason materials were rarely used across the two sites. Nonetheless, the knowledge gained from the separate design efforts in each site provided insights into the range of design challenges that might be faced in other contexts. This knowledge can, in turn, be used to support designs meant to be usable in a broader set of districts.

Built with district-wide use in mind, the curricula and professional development were robust enough to support inquiry-based teaching and learning in more than a handful of classrooms. They were also, to a certain extent, "unfinished." Their status as part of a design-based research project meant that these tools were never "complete" in the sense that a published curricula might be. The "unfinished" nature of the curriculum in particular is part of what made it so adaptable to the evolving needs of teachers and students. It is also part of why its development was a form of research — the best shape for that curriculum was still an open design question. Its unfinished nature, however, created challenges for its systemic use. Neither school districts nor universities are set up for the kind of materials production necessary to provide all teachers in districts the size of Chicago and Detroit with the most current versions. Moreover, it takes fairly dedicated teachers to work with such materials. The IQWST team is working on a more comprehensive and complete form of the curricula that can be used nation-wide. The success of the previously locally adapted materials raises questions about the localization of this new curricula. Will these new materials be adaptive in the same way? Will effective adaptations require the same kind of collaboration between teachers and researchers seen in LeTUS? To what extent can on-line systems like the *Living Curriculum* and *KNOW* support localization? And finally, will researchers be willing to engage in such collaborations if the resulting design work is not considered innovative enough to be research?

Finally, both sites found deep professional development strongly tied to localized practice an important part of building capacity for inquiry-based teaching within each district. While both sites had summer conferences or institutes and made one-on-one support available, the shape of their deepest professional development offerings was were quite different. The Saturday sessions in Detroit were built into the existing professional development infrastructure of the district, while the Lucent courses in Chicago were offered as graduate courses through Northwestern University. The Detroit system was successful at building a strong professional community within the district but because of the time commitment it required, might be limited in the number of teachers it can affect. In contrast, the Lucent course might be more accessible to a greater number of teachers, but was limited in terms of its ability to create a sustained professional community. In addition, both strategies relied on strong involvement and participation of researchers. These researchers provided the teachers with knowledge related to teaching and learning from the scholarly literature, as well as deep knowledge of science content related to the curricula. They also provided a conduit back to curriculum redesign. These conditions all raise questions about the optimum way to create professional development supports in other districts. To what extent is the involvement of researchers critical? Can support materials for teacher leaders or on-line systems such as *KNOW* replace some or all of their contributions? Under what conditions can such professional development be provided as part of districts' regular operation and under what conditions must it be supplied or supported by third parties, such as publishers and/or schools of education?

All of these questions about the trade-offs between localization and dissemination can only be answered through efforts to scale the work beyond the two currently involved districts.

The nature of success

In today's strong accountability climate, efforts like LeTUS need to demonstrate their viability in a number of ways in order to be considered successful. They especially need to show that they have real positive consequences for teaching practice and, more important, for student learning, particularly as measured by politically important state tests. It is simply not viable for districts to continue such a collaboration if it is not having a measurable pay-off for their students. Funders and policy makers are also concerned that the reform efforts employed are both scalable and sustainable. Does LeTUS only work in Chicago and Detroit? Does it require the researchers and the additional funding/infrastructure that come with them to sustain the work? Is the impact on students worth the time and money necessary to build, scale, and sustain the work?

The Center's original goal of integrating technology into classroom teaching and learning was a difficult one to meet. The challenge of creating a reliable and sustainable technological infrastructure to support science instruction in urban schools proved difficult at this time. However, the Center has been able to demonstrate to the satisfaction of the districts and funders that the curriculum is having a positive impact on students. Funders are willing to pay for a more complete curriculum to be built, and the districts have seen enough benefit from the current handful of replacement lessons produced to collaborate on the new work. The answers to the questions about scale and sustainability may not be fully answered until the new IQWST curriculum is available. However, there are hints to be found by comparing the nature of LeTUS's success in Detroit and Chicago.

It is impossible to investigate the history and story of LeTUS without making comparisons between the two sites. While they had common goals, values, and commitments, their contexts, working procedures and design solutions were in many ways quite different. A natural inclination is to ask the question, "Was one site more successful than the other?" At first glance, one might be tempted to nominate the Detroit team as the winner of such a horse race. The collaboration between the university team and the district seems deeper, and thus far they have been more successful at demonstrating improvements in student learning as measured by politically valued state tests. However, if sustainability is the goal, perhaps Chicago comes out ahead.

The centralized nature of Detroit's school system and Gray's strong role in directing the educational program in science allowed the Detroit branch of LeTUS to attack its work in a deeper and more systemic manner than in Chicago. But, in some ways, this relationship seems a bit idiosyncratic. Such a deep relationship with a district is rare, and dependent in many ways on the particular strengths of Gray and Steel. Both have a deep knowledge about science, science instruction, teachers, and professional development. More important, they are clearly respected by the teaching body they serve. This knowledge and respect, combined with the centralized nature of curriculum decisions in the Detroit Public Schools, facilitated their deep working relationship with the University. Replicating their vision and capacity for working closely with researchers in other settings might be difficult.

It is also not clear what would happen if the collaboration suddenly ended. It is highly *unlikely* that science instruction would fall apart if the hi-ce researchers were to leave. Gray, Steel, and their colleagues are highly competent professionals. They had made significant progress toward improving instruction via their USI before LeTUS was in place and had a long history of strong professional development in science. Moreover, LeTUS was just one piece (though perhaps a particularly useful and satisfying one) of their overall improvement agenda. However, the collaboration around professional development is fairly tight. The researchers currently serve as an important conduit for broadening the knowledge base of the teacher leaders as they plan those sessions.

Moreover, all the teachers interviewed felt the researchers played a pivotal and important role and none of them could imagine doing this work without them.

In contrast, LeTUS's efforts in Chicago were more piecemeal. The researchers and educators collaborating in that district had several more complex challenges to face: a lack of system-wide priority for the subject matter learning they were trying to support, a significant portion of the teaching population that lacked much formal training in the subject, a site-based management model that made system-wide efforts at reform difficult, and a lack of instructional vision within the district's original USI. Despite all these challenges, the Center has clearly had an enduring effect. Key personnel within the science portion of the new Chicago Mathematics and Science Initiative were deeply involved in LeTUS and their knowledge of the Center's efforts and intents have been part of the CM&SI's decision-making. The LeTUS teachers serve as resources for providing leadership in the current improvement efforts. The LeTUS curricula were used as a model to inform their decision-making around what instructional materials to adopt. And finally, the LeTUS researchers continue to serve as an intellectual sounding board and partner for the district. Thus Chicago provides evidence that the Center's approach *can* be used in less than ideal circumstances and still have a tangible and positive impact.

Moreover, the Chicago site also provides evidence that the impact of LeTUS may be sustainable beyond the existence of the collaboration itself. On the surface, the Center's impact was neither as strong nor as pervasive as it was in Detroit, nor were the LeTUS units as tightly woven into the District's improvement plans. At the same time, not all the teachers interviewed were convinced that the researchers' involvement was *necessary*. While they had many positive things to say about the role the researchers had played, several believed they could continue the work as long as some kind of professional community — perhaps composed largely of teachers — for supporting it was in existence. The teacher and district leadership cohort the project has left behind is active within the current Chicago Mathematics and Science Initiative and they are making a LeTUS-like imprint on that initiative. If the initiative can manage to build a professional community among those science education leaders, they have a chance at sustaining and growing beyond the progress made through LeTUS. While only time will tell if this impact is sustainable in the long-term, in the short-term it suggests that LeTUS has had an enduring and positive influence on the district beyond the role of the researchers.

So, was Chicago, in fact, more successful than Detroit? No. The relationship between University of Michigan and Detroit Public Schools is an incredibly powerful and productive one. Both the educators and the researchers involved have reaped significant benefits. They have made substantial improvements in teaching and learning within the district and major contributions to the research literature. It matters little whether this relationship can be repeated elsewhere. The fact that it improves the science education of several thousand students in Detroit is reason enough to continue the collaboration. In the end, Detroit and Chicago *collectively* show that the approach used in LeTUS is a viable one that can be used in districts with very different contextual constraints and still have a positive influence on teaching and learning. They also provide a range of design issues to consider when extending this work beyond the two sites, including the preferences, capacities and structures of the two districts. The current IQWST work will show whether their collective efforts have the potential to lead to materials, processes, and tools that are useful in other places.

The capacity of DBR for creating usable and useful knowledge

Reflection on this contrast between the nature of "success" in the two sites brings into relief a particularly thorny conundrum that underlies design-based research. The relationships formed between researchers and practitioners engaged in this work are often deep and not easily replicated in other contexts, much less on the kind of scale necessary to make significant improvements in education at large. The designs themselves are honed over successive iterations and with the support of personnel and equipment funded by the study. Hence, some see such efforts as "hothouse" designs that are too fragile to make it in the real world of classrooms that do not enjoy the specialized funding, attention, and support that come with participation in a research endeavor. When the robustness of the design is challenged, the usefulness of the knowledge embedded in or gained from that design is also challenged. Hence funders and policy makers are interested in evidence that design-based research can be scaled. But what does that mean exactly?

- Promulgating the designs created in initial classrooms into other classrooms?
- Expanding the design to encompass more of the curriculum?
- Using the technique of design-based research to take on systems larger than classrooms (e.g. schools, networks, or districts)?
- Using design-based research techniques as a means of addressing questions of scale? or
- Using design-based research techniques to create innovations with the capacity to scale?

It could be argued that LeTUS engaged in all five of these activities. By taking on districts as their unit of design, the project used the technique with a system larger than a classroom. In doing so, they explicitly took on questions of scale as part of their design challenge (Blumenfeld, 2000; Fishman et al 2004) and created innovations robust enough to be promulgated in classrooms across those districts with sufficient coverage of the curriculum to be worth each district's while. Moreover, in the process of doing so, they crafted models of both curriculum design and professional development design that they believe can be used to take this work beyond the classrooms in these two initial districts (Fishman et al., 2003, April; Reiser, Krajcik, Moje & Marx, 2003).

The research and development path in which LeTUS is situated also suggests that scaling design-based research may be a matter of iteration. Small scale and detailed work, such as that done by PBS, BGuILE, and CoVis may be necessary to understand the basic needs of teachers and students and create fledgling versions of innovations. Scaling in a moderate fashion (as LeTUS did) can provide the opportunity to make those innovations more robust, while still allowing the kind of close collaboration necessary to do strong redesign. Moreover, this moderate scaling can lead to the development of capacity within districts for supporting the innovations that makes further scale and refinement possible.

In part, LeTUS was successful in scaling the work to include as many teachers and classrooms as it did because a significant portion of the support and service aspects of the work were *shared* by the districts. Finally, the moderate scaling can lead to the development of design principles for bringing the innovation to a scale that can then be used to refine the innovation for a national audience.

Each stage of the work requires shifts both in research techniques and in modes of collaboration between researchers and educators. Small-scale design-based research requires deep relationships with a handful of teachers and research designs that provide detailed understanding of classroom activity and student and teacher learning. Moderate, scale design-based research requires collaboration with district and/or school leaders on the design of systemic reform and support and simultaneously with some portion of teachers on issues of classroom design. Research designs must span both large-scale and small-scale evaluations of teaching and learning and they must be sensitive to the participating district's accountability needs.

Whether IQWST incorporates a form of design-based research done on a national scale, or a more traditional form of research and development that disseminates the innovations from early design-based research to a national audience, remains to be seen. The IQWST work was not a focus of this study, but their work was touched upon by the participants interviewed. Their current efforts at redesigning the curriculum seem to involve a more traditional research and development structure overall, with the lion's share of the design work done by researchers based upon their past work. However, their piloting efforts are likely to look somewhat like small-scale design-based research. Probably the research instruments for evaluating teaching and learning will also change, but the IQWST team's plans in this regard were not investigated for this study.

What LeTUS does not tell us is whether all of these stages are necessary. Can others use their models for design in order to work at national scale from the beginning? In other words, do the design principles and processes themselves serve as a form of useful and usable knowledge for others? Or is the early close work necessary in order to have a firm knowledge base about content, student learning, and teacher learning that will inform the designs? Is the establishment of a moderate-scale design and research context — as done through LeTUS — necessary? Both for the design insights it brings as well as the relationships and infrastructure it affords?

The current operating procedures of LeTUS/IQWST suggest that scaling may not be so much a process of moving through stages, as adding new and expanding layers of collaboration and innovation to work already being done. The LeTUS researchers have a number of related grants at the current time. Some explore new designs with a small number of teachers in much the way pre-LeTUS work was conducted. Others are related to studying and/or supporting work within the original two LeTUS districts and still others, such as IQWST, are aimed at taking the work to a national audience. This multi-layered work enables the researchers and educators to pursue cutting-edge innovations at the same time they are attempting solidify and codify others. The close work with the individual teachers and districts, keeps their work grounded. Moreover, the continuing relationships with the districts give the researchers access to a natural testbed for working out some of their scaled plans in real settings with collaborators with whom they have a trusting and forthright relationship and under conditions where some of the systemic support for their work is in place. If the result is a more comprehensive curriculum that the districts can use to push reform more systematically, then all will benefit.

REFERENCES

Achieve, Inc. (2001). *Briefing book*. 2001 Educational Summit, Palisades, NY, October 9-10, 2001. [On-line: www.achieve.org]

American Association for the Advancement of Science. (1990). *Science for all Americans: Project 2061*. New York: Oxford University Press.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

American Association for the Advancement of Science. (2001). *Atlas for scientific literacy*. Washington, D.C.: AAAS.

Ball, D. L. & Cohen, D. K. (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., Fishman, B. J., Krajcik, J., Marx, R. W. (2000). Creating usable innovations in systemic reform: Scaling up technology-embedded project-based science in urban schools. *Educational Psychologist, 35* (3), 149-164.

Brown, A. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences, 2* (2), 141-178.

Brown, A. & Campione, J. (1996). Psychological theory and the design of innovative learning environments: On procedures, principles and systems. In L. Schauble and R. Glaser (Eds.), Innovations in learning: New environments for education (pp. 289-325). Mahwah, NJ: Lawrence Erlbaum Associates.

Cobb, P., Confrey, J., diSessa, A., Lehrer, R., Schauble, L. (2003). Design experiments in educational research. *Educational Researcher, 32* (1), 9-13.

Cognition and Technology Group at Vanderbilt. (1997). The Jasper Project: Lessons in curriculum, instruction, assessment and professional development. Mahwah, NJ: Lawrence Erlbaum Associates.

Collins, A. (1992). Toward a design science of education. In E. Scanlon & T. O'Shea (Eds.), *New directions in educational technology*. New York: Springer-Verlag.

Collins, A. (1999). The changing infrastructure of education research. In E. C. Lageman & L. S. Shulman (Eds.), *Issues in education research: Problems and possibilities*. San Francisco: Jossey-Bass.

Collins, A., Joseph, D., and Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *Journal of the Learning Sciences, 13* (1), 15-42.

D'Amico, L. (1999, April). The implications of project-based pedagogy for the classroom assessment infrastructures of science teachers. Paper presented at the Annual Meeting of the Americal Educational Research Association, Montréal, Québec, Canada.

Dede, C. (2004). If design-based research is the answer, what is the question? A commentary on Collins, Joseph, and Bielaczyc; diSessa and Cobb; and Fishman, Marx, Blumenthal[sic], Krajcik, and Soloway in the *JLS* special issue on design-based research. *Journal of the Learning Sciences*, *13* (1), 105-114.

Design-based research collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32* (1), 5-8.

Edelson, D. C. (2001). Learning-for-use: A framework for the design of technology-supported inquiry activities. *Journal of Research in Science Teaching, 38*, 355-385.

Fishman, B. (2003). Linking on-line video and curriculum to leverage community knowledge. In J. Brophy (Ed.), *Advances in research on teaching: Using video in teacher education (Vol. 10)*. New York: Elsevier, 201-234.

Fishman, B. J., Marx, R. W., Best, S., Tal, R. T. (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and Teacher Education*, 19, 643-658.

Fishman, B., Fogleman, J., Kubitskey, B., Marx, R., Margerum-Leys, J., Peek-Brown, D. (2003, March). Taking charge of innovations: Shifting ownership of professional development with a district university partnership to sustain reform. A paper presented at the Annual Meeting of the National Association for Research on Science Teaching, Philadelphia, PA.

Fishman, B., Hug, B., Honey, M., Light, D., Marx, R., & Carrigg, F. (2003, April). Exploring the portability of reform: One district's approach to adaptation. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago, IL.

Fishman, B., Marx, R. W., Blumenfeld, P., Krajcik, J., Soloway, E. (2004). Creating a framework for research on systemic technology innovations. *Journal of the Learning Sciences, 13* (1), 43-76.

Gomez, L. M., Fishman, B. J., & Pea, R. D. (1998). The CoVis Project: Building a large scale science education testbed. *Interactive Learning Environments* [Special issue on telecommunications in education].

Gomez, L., Marx, R., Soloway, E., Schank, R., Clay-Chambers, J. & Burgess, C. (1997). Center for Learning Technologies in Urban Schools (Project Description). Grant proposal submitted to the National Science Foundation. Washington, D.C.

Grier, R., Blumenfeld, P. Marx, R., Krajcik, J. Fishman, B. & Soloway, E. (2004). Standardized test outcomes of urban students participating in standards and project-based science curricula. In Y. B. Kafai, W. A. Sandoval, N. Enyeady, A. S. Nixon, F. Herrera (Eds.), *Proceedings of the Sixth International Conference on the Learning Sciences*, June 22-26, 2004, University of California Los Angeles, Santa Monica, CA. Mahwah, NJ: Lawrence Erlbaum Associates.

Hatch, T., & White, N. (2002). The raw materials of reform: Rethinking the knowledge of school improvement. *Journal of Educational Change*, *3*, 117-134.

Herman, P., Mackenzie, S., Sherin, B. and Reiser, B. (2002, October). Assessing student learning in project-based science classrooms: Development and administration of written assessments. Paper presented at the International Conference of the Learning Sciences, Seattle, WA.

Herman, P., Mackenzie, S., Reiser, B. and Sherin, B. (2003). Student learning in the *Earth Structures* Unit. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago, IL, April, 2003.

Herman, P., Mackenzie, S., Rose, K. (2003). Student learning in the *Water Quality* Unit. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago, IL, April, 2003.

Jackson, S. L., Stratford, S. J., Krajcik, J. & Soloway, E. (1994). Making dynamic modeling accessible to precollege science students. *Interactive Learning Environments*, 4, 233-257.

Kelly, A. E. (2003). Research as design. *Educational Researcher, 32* (1), 3-4.

Kolodner, J. L. (1991). The journal of the learning sciences: Effecting changes in education. *Journal of the Learning Sciences, 1* (1), 1-6.

Krajcik, J. S., Blumenfeld, P. C., Marx, R. W. & Solowy, E. (1994). A collaborative model for helping teachers learn project-based instruction. *Elementary School Journal, 94*, 483-497.

Krajcik, J. S., Blumenfeld, P. C., Marx, R. W., Fredricks, J., & Soloway, E. (1998). Inquiry in project-based science classrooms: Initial attempts by middle school students. *The Journal of the Learning Sciences, 7* (3 & 4).

LeTUS Team, University of Michigan. (2003, June). MEAP Analysis. Powerpoint slides from a presentation to Detroit Public School principals.

Linn, M. C. & Songer, N. B. (1991). Teaching thermodynamics to middle school students: What are appropriate cognitive demands? *Journal of Research on Science Teaching, 28* (10), 885-918.

Marx, R. W., Blumenfeld, P., Krajcik, J.S., & Soloway, E. (1997). Enacting project-based science. *Elementary School Journal, 97* (4), 341-358.

Marx, R. W., Blumenfeld, P.C., Krajcik, J. S., Fishman, B., Soloway, E., Geier, R., Tal, R. T. (2004). Inquiry-based science in the middle grades: Assessment of learning in urban systemic reform. *Journal of Research on Science Teaching, 41* (10), 1063-1080.

Middleton, M. Blumenfeld, P.C., Marx, R. W. (2004). Connecting standards based instruction, motivation and achievement in urban middle school science classrooms. Paper presented at the 2004 Annual Meeting of the American Educational Research Association, San Diego, CA.

Moje, E. B., Sutherland, L. M., Krajcik, J., Blumenfeld, P., Peek-Brown, D., Marx, R. W. Reading and writing like scientists: Toward developing scientific literacy in project-based science. (2004, November). Paper presented at the 82nd Annual Convention of the National Council of Teachers of English, Indianapolis, IN.

National Research Council. (1996). *National science education standards*. Washington, D.C.: NRC.

Pea, R. D. (1993). The collaborative visualization project. *Communications of the ACM, 36* (5), 60-63.

Pea, R. D., & Gomez, L. M. (1992). Distributed multimedia learning environments: Why and how? *Interactive Learning Environments, 2*(2), 73–109.

Pelligrino, J. W., Chudowsky, N. & Glaser, R. (Eds.) (2001). *Knowing what students know: The science and design of educational assessment*. Washington, D.C.: National Academy Press.

Polman, J. L. (2000). *Designing project-based science: Connecting learners through guided inquiry*. New York, NY: Teachers College Press.

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., Kyza, E., Edelson, D., & Soloway, E. (2004). A scaffolding design framework for software to support science inquiry. *Journal of the Learning Sciences, 13* (3), 337-386.

Reiser, B. J. (2004). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *Journal of the Learning Sciences, 13* (3), 273-304.

Reiser, B. J., Krajcik, J., Moje, E., Marx, R. (2003). Design strategies for developing science instructional materials. A paper presented at the 2003 Annual Meeting of the National Association of Research in Science Teaching, Philadelphia, PA.

Reiser, B. J., Tabak, I., Sandoval, W. A., Smith, B. K., Steinmuller, F., and Leone, A. J. (2001). BGuILE: Strategic and conceptual scaffolds for scientific inquiry in biology classrooms. In S. M. Carver and D. Klahr (Eds.), *Cognition and* *instruction: Twenty five years of progress* (pp. 263-305). Mahwah, NJ: Lawrence Erlbaum Associates.

Rivet, A. E., Krajcik, J. S. (2004). Achieving standards in urban systemic reform: An example of a sixth grade project-based science curriculum. *Journal of Research in Science Teaching*, *41* (7), 669-692.

Sandoval, W.A. (2003). Conceptual and epistemic aspects of students' scientific explanations. *Journal of the Learning Sciences, 12* (1): 5-51.

Scardemalia, M. & Bereiter, C. (1994). Computer support for knowledge-building communities. *Journal of the Learning Sciences, 3* (3), 265-283.

Schneider, R. M. & Krajcik, J. (2002). Supporting science teacher learning: The role of educative curriculum materials. *Journal of Science Teacher Education, 13* (3), 221-245.

Schneider, R. M., Krajcik, J. & Blumenfeld, P. (2005). Enacting reform-based science materials: The range of teacher enactments in reform classrooms. *Journal of Research in Science Teaching, 42* (3), 283-312.

Shrader, G. W. & Gomez, L. M. (1999). Design research for the Living Curriculum. In C. Hoadley & J. Roschelle (Eds.), *Proceedings of Computer Support for Collaborative Learning '99*, Palo Alto, CA: Erlbaum.

Shrader, G. W., Whitcomb, J., Finn, L. E., Williams, K. P., Walker, L. J., & Gomez, L. M. (1999). Work in the "Work Circle": A description of collaborative design to improve teaching practice. A paper presented at the Spencer Foundation Conference on Collaborative Research for Practice, New Orleans, LA.

Shrader, G. Williams, K., Gomez, L., Lachance-Whitcomb, J., Finn, L. E. (in review). Participatory design of science curricula: The case for research for practice. [Manuscript in review dated April 2003].

Singer, J., Marx, R. W., Krajcik, J., Chambers, J. C. (2000). Constructing extended inquiry projects: Curriculum materials for science education reform. *Educational Psychologist, 35* (3), 165-178.

Tabak, I. (2004). Synergy: A complement to emerging patterns of distributed scaffolding. *Journal of the Learning Sciences, 13*(3): 305-335.

U.S. Department of Education, Office of Elementary and Secondary Education. (2002). *No child left behind: A desktop reference*. Washington, D.C.

Wiggins, G. P. & McTighe, J. (1998). *Understanding by design*. Alexandria, VA: Association for Supervision and Curriculum Development.

OTHER SOURCES

LeTUS website (www.letus.org)

Award abstracts from NSF for:

(1) LeTUS
(http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=9720383)

(2) The Living Curriculum Project
(http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=9720423)

(3) Using Information Technologies to Support Middle School Students in Scientific Inquiry Project
(http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=9725927), and

(4) Teaching Strategies to Promote the Construction of Science Understanding in Urban Schools
(http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0106959)

Application by hi-ce group at University of Michigan for an Urban Impact Award submitted to Council of the Great City Colleges of Education, Washington, D.C., May 28, 2004.

Brochure for the Center for Curriculum Materials in Science.

Curriculum vitae for selected LeTUS researchers.

APPENDIX A: KEY PLAYERS

There are numerous teachers, graduate students, post-doctoral researchers, computer programmers and administrative staff involved in the LeTUS Center (and its affiliated projects), as well as faculty who play an adjunct role. The original funding proposal to NSF lists six co-principle investigators: Louis Gomez and Roger Schank at Northwestern University; Clifton Burgess at the Chicago Public Schools; Ronald Marx and Elliot Soloway at University of Michigan; and Amelia Gray at Detroit Public Schools.[24] Listed below are the people who emerged as core personnel during the interviews. Those with

(*) by their names were involved in one-on-one interviews in June 2003, and

(°) by their names were involved in one-on-one interviews in June 2004, and

(†) by their names were involved in focus group interviews in June 2004.

Detroit Public Schools[25]

- **Amelia Gray°**: Co-director of LeTUS representing Detroit Public Schools; Chief Academic Officer of DPS works very closely with the University of Michigan group; during the course of LeTUS, DPS has reorganized the central office more than once and her title has changed several times as a result, but she's always had a strong influence on district curriculum policy.
- **Barbara Steel*†**: LeTUS instructional specialist; serves as liaison between hi-ce and Detroit Public Schools for LeTUS; former science teacher; worked with the hi-ce team on the PBS project; conducted and oversaw most of the professional development provided for the Detroit teachers in consultation with Fishman and his team; supported teachers in the classroom; planed LeTUS related professional development for principals; recruited new LeTUS teachers.
- **Stella Novak†:** Science teacher in Detroit Public Schools; part of the design team for the LeTUS curriculum; served as a lead teacher for the professional development of LeTUS teachers in Detroit.

University of Michigan

- **Phyllis Blumenfeld†**: Professor of Education; focused on classroom-based research; organized and led much of the classroom data collection; founding member of the hi-ce group.
- **Barry Fishman*†**: Assistant/Associate Professor of Education; took over primary responsibility for research on professional development; interested in

[24] Schank was involved in the grant writing. However, he left the Northwestern University not long after the grant was received and never became actively involved in the center. Burgess was head of the Chicago Systemic Initiative as well as a LeTUS co-director through the spring of 2003 when Chicago acquired a new superintendent and along with him, a new organization for the district administration. Marty Gartzman, Chief Officer in Mathematics and Science, essentially replaces Burgess.

[25] The names listed for Detroit Public School employees are all pseudonyms in accordance with district requirements for research conducted in Detroit schools.

policy changes at the district level that need to be made to support the work–particularly technology intergration; current member of hi-ce group; former CoVis graduate student with a Ph.D. from Northwestern; only person to cross between the sites.

- **Joe Krajcik*†**: Professor of Education; a science educator by training and the heart of the curriculum design and management team in Detroit; worked closely with science curriculum professionals in the Detroit Public Schools; helped design and implement early professional development for LeTUS in Detroit; founding member of the hi-ce group.
- **Ron Marx*°**: Co-director of LeTUS for University of Michigan; Professor of Education; part of the core curriculum design management team; leader of hi-ce's efforts to devise instruments for measuring the effects of their work on student learning and motivation; founding member of the hi-ce group.
- **Elizabeth Moje**: Associate Professor of Education; studied literacy as a tool in the academic disciplines; investigated the roles of culture and community in content area literacy; worked on the development of scientific literacy practices in LeTUS classrooms.
- **Jon Singer**: Former post-doc and member of the core management team that over saw curriculum design for the Detroit branch of LeTUS; currently collaborates on follow-up grants to LeTUS from his position as an Assistant Professor at a university in South Carolina.
- **Elliot Soloway**: Professor of Electrical Engineering and Computer Science; Professor of Education; directed most of the software development and exploration of technological innovations for the hi-ce team; founding member of the hi-ce group.

Chicago Public Schools

- **Clifton Burgess:** Co-director of LeTUS for Chicago Public Schools; head of the Chicago Systemic Initiative; no longer involved in district offices related to science education.
- **Martin Gartzman**: Chief officer for Mathematics and Science in the Chicago Public Schools; in charge of the Chicago Mathematics and Science Initiative (CM&SI) that succeeded the Chicago Systemic Initiative.
- **Michael Lach°**: Director of Science for the CM&SI in the Chicago Public Schools; former Chicago Public Schools teacher; worked for two years on high school environmental science curriculum with Danny Edelson.
- **Chandra James**: LeTUS coordinator inside CPS; currently elementary science manager for the CM&SI; worked closely with Lou-Ellen Finn to organize and provide professional development on LeTUS curricula and technology for Chicago teachers; assisted in recruiting new teachers for LeTUS.

Northwestern University

- **Danny Edelson†**: Associate Professor of Learning Sciences and Computer Science; directed development of specific software and associated curricula; involved in the development of their professional development approach and their evaluation efforts; director of the Ph.D. program in the Learning Sciences and the Northwestern University contact for the Center for Curriculum Materials in Science, a Ph.D. and post-doctoral program that grew out of LeTUS.
- **Lou-Ellen Finn*†**: Director of professional development for Northwestern; worked closely with Chandra James; started as a LeTUS teacher; did considerable work on curriculum development, including participation in the ReNUE work circle.
- **Louis Gomez*†°**: Co-director of LeTUS for Northwestern University; Professor of Learning Sciences and Computer Science; did much of the school/district level liaison work in Chicago; served as "Executive" director of the center for a time.
- **Phillip Herman*†**: Research Assistant Professor of Learning Sciences; director of Research for NWU LeTUS team; led the effort to develop, administer, score and analyze unit pre and posttests, as well as questionnaires and other measures of the effects of the LeTUS project on student learning and attitudes.
- **David Kanter†**: Research Assistant Professor of Learning Sciences and Affiliated Faculty, Biomedical Engineering Department; with teachers and other experts, co-designed and developed middle and high school biology curricula; conducted classroom research on student learning.
- **Brian Reiser***: Professor of Learning Sciences; directed development of specific software and associated curricula; helped coordinate curricula development for Northwestern team; key player in the development of pre and posttests for evaluating the LeTUS curricula developed at NWU.
- **Bruce Sherin†**: Associate Professor of Learning Sciences; involved in the study of student learning in LeTUS curricula as part of the NSF-funded Conceptual Dynamics project; participated in the development of unit pre- and post-tests.
- **Greg Shrader***: Research Assistant Professor of Learning Sciences; actively involved with LeTUS during its first four years of funding; Director of Professional Development for two of those years; co-developed curricula with Chicago teachers and led ReNUE work circle; former CoVis graduate student; not closely involved with LeTUS during its last couple years.
- **Jim Spillane**: Professor of the Learning Sciences and Human Development and Social Policy; conducted study of distributed leadership in schools within the context of LeTUS.

APPENDIX B: LETUS CURRICULUM OVERVIEW

Chicago and Northwestern Curricula	Detroit and U. Michigan Curricula
Behavior Matters (6th grade) • *Question*: What is animal behavior, how do we study it and how does it relate to conservation? • *Science content*: Animal behavior, conservation principles and scientific method **Earth Structures** (6th grade) • *Question*: How will the movement of tectonic plates affect the earth's crust? • *Science content*: Earth's crust, plate tectonics, earthquakes, volcanoes, latitude and longitude, modeling, map reading, geography **Struggle for Survival** (6th grade) • *Question*: What is causing an island ecosystem crisis, and how are some animals managing to survive? • *Science content*: Complex ecosystems, natural selection, species interaction	**BioKids** (6th grade) • *Science content*: Ecosystems and biodiversity **Kids as Global Scientists** (6th grade) • *Question*: What makes our weather? • *Science content*: Clouds and humidity, wind, temperature, precipitation and pressure, energy transfer, Earth as a system **Simple Machines** (6th grade) • *Question*: How do machines help me move big things? • *Science content*: Force, motion, distance, simple machines
I, Bio (7th grade) • *Question*: How well do my school lunch choices meet my body's energy needs? • *Science content*: Cells, energy transformation, organ systems, human biology, health, physiology, physics, cell structure and function **ReNUE** (7th grade) • No longer in use. (Not on LeTUS website) **Solar Energy** (7th grade) • *Question*: Can y ou design a habitable house using only passive solar energy? • *Science content*: Energy transfer, heat transfer, renewable and nonrenewable energy resources, insulation	**Air Quality** (7th grade) • *Question*: What affects the quality of the air in my community? • *Science content*: Chemical and physical properties of pollutants **Communicable Diseases** (7th grade) • *Question*: How can good friends make me sick? • *Science content*: The biology of disease, how diseases spread and how our bodies fight them; also covers STDs. **Water Quality** (7th grade) • *Question*: What is the water like in our river? • *Science content*: Watersheds, erosion and deposition, how chemistry and biology affect water quality
Global Warming (8th grade) • *Question*: Why do scientists think people are making the Earth's climate warmer? • *Science content*: Temperature, energy balance, population, and carbon emissions **Planetary Forecaster** (8th grade) • *Question*: What are the major factors that affect surface temperature and how do each of these factors affect temperature? • *Science content*: Curvature of the Earth's surface, the tilt of the Earth's axis, land/water differences in specific heat, surface elevation **Water Quality** (8th grade) (They use the UMich/DPS unit.)	**Bike Helmet** (8th grade) • *Question*: Why do I need to wear a bike helmet? • *Science content*: Motion, force, velocity, acceleration

Notes: Grade levels for Chicago are those suggested by the Center based on their match to CPS' Standards and Frameworks. However, because the curriculum is not standardized, teachers in the district, often use them at grade levels other than those suggested. BioKIDS and Kids as Global Scientists are both projects run by Dr. Nancy Songer at University of Michigan, who is neither a participant in LeTUS nor a member of hi-ce. Nonetheless, her curriculum and activities are offered to district teachers under the LeTUS umbrella.

APPENDIX C: EXCERPTS FROM LETUS CURRICULA

Included are short excerpts from one unit from each of the two sites.

- *ReNUE* was chosen as an example from Chicago/Northwestern University because it is highlighted in this report.
- *How Can Good Friends Make Me Sick?* (Communicable Disease unit) was chosen from Detroit/University of Michigan because it has been written about elsewhere in detail, including its adaptation in another district (Fishman, Hug, Honey, Light, Marx, & Carrigg, 2003).

Each unit is actually quite long. *ReNUE* includes about 20 lessons, each 1-5 pages in length and takes about 30-35 class periods to complete. *How Can Good Friends Make Me Sick?* contains 19 lessons that encompass 42 days or class time and is over 125 pages long.

For each unit, some of the overview material and a lesson or two is provided to give a feel for how the structure of the curriculum was both similar and different in the two locations.

ReNUE

Realizing New Urban Environments

A Curriculum Overview

This curriculum examines urban environmental problems. Phase A of the curriculum contains introductory activities designed to help students identify environmental issues and to familiarize them with the process of group work. An introduction to the Internet begins phase B and is followed by the research segment of the project. In phase C , modeling, students construct a model of their problem both on paper and on the computer using Model Builder, a software program designed to help students with scientific modeling. Finally, in phase D, students present their problems and solutions orally and in written form.

A PHASE A: THE INTRODUCTION

Phase A of the ReNUE curriculum contains introductory activities which are designed to help students identify environmental issues and familiarize them with the process of group work. This phase begins with The Lorax in Lesson A1, which introduces terms that will be used in the unit and continues with work sessions in order to familiarize them with the group process. Group work is again reinforced in activities A2 and A3 in which groups are asked to produce specific artifacts while working together. Lesson A4 has students practice using latitude and longitude to find cities and then each group is given a set of coordinates for the city that they will be studying during the project. The final lesson in this phase, A5, introduces students to the ReNue project itself and the deliverables they must produce. It also engages them in a sustained discussion about the project and the work involved by getting them to set their own deadlines. The end goal of Phase A is for students to use the background activities to learn environmental concepts.

B PHASE B: RESEARCH

In Phase B, students will learn to use the research tools necessary for successful completion of the project. The beginning lesson, B1, introduces the Internet, and gives hands on experience on how to use it. The next lesson aids the student in determining credible sources, a skill that needs to be used any time the Internet is accessed for research. While students learn how to research, they will also be developing problem statements based on the research they have completed. Optimally, they will be able to contact mentor scientists via e-mail. These professionals will assess the written problem statements, and also answer any questions the students may have relative to the model they are going to construct in the next phase. There are several jigsaw lessons in Phase B which allow students to share what their group has learned with each of the other groups. The end goal of Phase B is for the students to produce a cause and effect problem statement for their city.

C PHASE C: MODELING

Phase C is the Modeling phase of the curriculum. In this phase, students will first construct a paper model of the environmental problem within their city. They will learn to identify objects, variables and relationships that are connected with the problem. They will then move to using the Model-It software program, entering their data into the program and manipulating the data to see relationships between objects and variables. Through these lessons they will develop an understanding of the complex and multiple interactions and interdependencies that occur within all ecosystems. They will then be ready to move on to the final phase of the project, a presentation of their findings. The end goal of Phase C is to build a systemic model of their environmental problem using Model-It software.

D PHASE D: PRESENTATIONS

Phase D is the culmination of the activities covered in the rest of the curriculum. It is in this phase that the students demonstrate their understanding of the impact of humans and technology on the balance of interdependence and interactions with an ecosystem. They do this by combining their findings from Internet research and Model-It models to create group oral, visual, and written presentations. In the oral presentation, each student in the group presents a portion of the project. The purpose of this is to have students persuade the audience that their conclusions are valid, and their solution is backed by valid research. In the visual portion, each group will present its findings either on a three-sided display board or in a Power Point or other computer generated presentation format. Finally, a group research paper is to be submitted, following the formal research paper format used within the scientific community.

THE LORAX

A1

1 to 2 Class Periods

Overview: *This lesson focuses students on the environmental problems from the vantage point of causes and effects. Through effective questioning, the instructor can have students review and reinforce ecosystem concepts as well as initiating thought processes on the complexity of the issues.*

Vocabulary (introduced or reviewed)

abiotic	non-living elements in an ecosystem
biotic	living or once living elements in an ecosystem
ecosystem	organisms interacting with a particular environment. It includes all of the biotic and abiotic elements
interaction	actions taking place between elements in an ecosystem
interdependence	organisms need for other elements in the ecosystem

Materials

- "Lorax" Video (30 minutes)

OR

- Lorax book
- Science journals

Procedures

- Discuss the terms ecosystem, interaction, and interdependence
- Show the film.
- Instruct students to take notes on anything in the video that involves interaction and interdependence.
- Have students discuss notes taken.
- Assign homework.

Homework

Students will:

- explain interdependence and interaction to their parents; ask parents to help identify examples of interaction and interdependence in their own neighborhood; record examples in their science journals.

Correlations

CPS SG 12 B, 1,2,3,4

Prerequisite

- None

Objective

- Defining ecosystems in terms of interaction and interdependence

Teacher Note

- Begin day two with a brief discussion of examples students have recorded.

Enrichment

- The Lorax concludes with a caution "...unless". Ask students to write their interpretation of what that would mean.

A3

INTRODUCTORY GROUPING/ BRAINSTORMING ACTIVITY

1 Class Period

Overview: *Groups structure their brainstormed urban environmental problems within a word web in order to organize ideas and provide a basis for identifying causes of these problems.*

Correlations

CPS 12 B 1,2,3,4

Prerequisite

- None

Objective

- Developing positive interaction skills

Identifying possible causes of problems in an urban environment

Teacher Note

- In doing this lesson, students may suggest an environmental problem for which we do not have support materials. You may direct your students to choose one of our problems or research their own and develop their own materials.

Vocabulary (introduced or reviewed)

environment	the physical surroundings of an organism, including all biotic and abiotic conditions and circumstances that affect its development
environmental problem	any created disruption of a particular environment

Materials

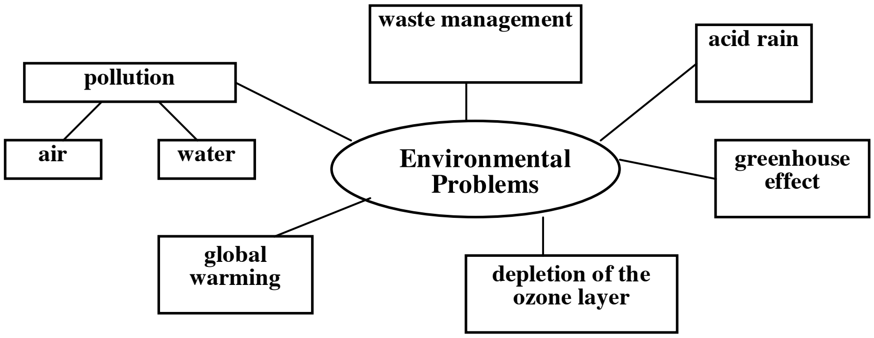
- Approximately 50 Post-it™ Notes (3” x 5”)
- pens or pencils

Procedures

- Determine groups prior to lesson. If students are familiar with working in groups, let students choose with whom they wish to work.
- Present the following discussion questions orally as you write them on the chalkboard or overhead.
    1. What is meant by the term environmental problem?
    2. What are some specific environmental problems that you have observed or know about?
    3. What are the effects of these environmental problems on animals? On plants? On humans? On the earth?
- Direct groups to begin discussion of each question, remembering that each child has a voice and that all answers should be agreed upon by consensus.
- Direct groups to choose a secretary to record specific environmental problems on individual Post-it™ Notes. (Note: List only one environmental problem on each Post-it™ Notes).
- Remind groups that they have 20 minutes to complete this task. (Note: If you know that your students are capable of doing this part of the activity in a shorter period of time, adjust the total time allowed.)

- Construct a simple word web on the chalkboard with "environmental problems" at the center.

Example: *(Your classrooms may have different and/or additional problems.)*



- Ask the groups to choose a speaker to present one problem they discussed and to place the Post-it™ Notes on the word web.
- Allow each group to present one different problem at a time until all choices have been presented.
- Address any misconceptions the students may have about a particular problem. (Note: It may be necessary to distinguish between social problems and environmental problems if they suggest such things as graffiti and gangs.)

Variation:

- Write a short group paper explaining the choices that were made and why the group made them.

Teacher Notes:

- Before tomorrow's Lesson (A4), you will need to place students in groups based on their choice of an environmental problem. It is fine to have more than one group studying the same environmental problem. Ideally groups should have between 3 and 5 members.
- The ReNUE Project is organized around 6 case studies. Based on student's interest, you should place them in groups around the following case studies:

  Air Pollution

  Water Pollution-Waste Management

  Water Pollution-Industrial Waste

  Landfill-Industrial Waste

  Acid Rain

  Nuclear Meltdown

DRAFT '00-01

How Can Good Friends Make You Sick?

Organization of the Communicable Disease Unit

Driving Questions

This unit is organized around a "Driving Question." A Driving Question has three characteristics: 1) It needs to be worthwhile and consistent with existing curriculum frameworks, including district and state guidelines; 2) it needs to encompass real-world problems that students find meaningful; and, 3) the question needs to be feasible and allow students to develop the knowledge and skills necessary to answer the question. The Driving Question for this unit is "How can good friends make you sick?". This question is open-ended and focuses investigations throughout an extended period of time.

Learning Sets and Sessions

In this project, the Driving Question is divided into four related sub-questions. Learning Sets are organized around a sub-question that contains related concepts and activities. The purpose of the sub-questions is to help the students construct a response that will demonstrate their emergent understanding of the concepts and processes which are central to the Driving Question. Learning Sets last 1-4 weeks, depending on the complexity of the concepts being focused on. Each Learning Set begins with the purpose of the Learning Set, a calendar, background content information, an overview and, detailed lesson plans. Learning Sets are further divided into Sessions. A Session is a specific activity that focuses on a single concept. It provides content information related to the topic of the Learning Set and, ultimately, the Driving Question. Sessions last 1-5 days and contain detailed plans for enacting activities.

Learning Sets and Sessions for this unit are:

- Is anyone sick?
    - Are you sick?
    - What is a disease?
- What makes me sick?
    - What causes disease?
    - Where do bacteria grow?
    - What affects the growth of bacteria?
    - Are they alive?
    - Modified Michigan Model activity: Connection to specific diseases
    - Artemis Investigation on diseases
- Why do diseases spread?
    - How do diseases spread?
    - Why do diseases spread?
    - Making connections
- What happens to me when I get sick?
    - What happens to me when I get infected?
    - How does my body protect me?
    - Why doesn't the immune system always work?
    - How can bacteria and viruses move around me?
    - How will it affect me when I'm older?
    - Building the connections
- Disease Investigation presentations

Projects

The Disease Investigation is a unit long investigation that students do on one particular disease. Students work in groups of two or four to investigate this disease. Students will investigate one of the following diseases: cholera, hepatitis, herpes, HIV/AIDS, influenza, the plague, syphilis, and West Nile encephalitis. These diseases were selected for student investigation based on the potential for student engagement. A mix of diseases are provided so that depending on the maturity of the students and the school setting, sexually transmitted diseases can be selected for investigation or not. If sexually transmitted diseases are selected for use make certain that mature individuals are given the sexually transmitted diseases to investigate. The investigation draws from in-class activities, student readings, the use of an on-line environment and additional materials provided in the curriculum. While the Disease Investigation draws heavily from the use of the World Wide Web, it can be done successfully with only the other curriculum materials if no connection to the Web is available. The Disease Investigation is an excellent opportunity for the student to create and the teacher to evaluate artifacts.

Student Reader

The Student Reader is a set of supplemental reading material for the student. This reading material is written so that it provides an additional representation of the concepts investigated in class. In addition, the student reader provides additional material that the students can draw upon for the Disease Investigation. Because the students are divided into groups for the Disease Investigation, the Student Reader addresses each group individually. Because of this, there are eight different Students Readers that the students and teacher can use. One specific Student Reader is provided for each disease. The Student Reader is structured so that students read similar material about the main scientific content but different information about a specific communicable disease. Because of the content presented in the Student Reader, mature students should be selected for the group reading about specific sexually transmitted diseases. The reader should be drawn into class discussion when appropriate since this will give students ownership of the specific diseases that they are investigating. They will be the experts in charge of instructing the other students. Throughout the unit, students contribute information that they learn from the Student Reader and the unit investigations to a Disease Chart that outlines the different characteristics of all the diseases under investigation.

Icons

Throughout this unit, pictures (icons) are used to represent key aspects of the project, such as teaching strategies, content information, and technology and, anchoring experiences. These icons, found on the right side of the page, are meant to help you enact the project by highlighting and providing helpful hints. (See next page).

Project Overview

How can good friends make you sick? This question drives student inquiry throughout this project. As students investigate different causes of disease and how their body fights off disease, they develop an understanding about the biology behind these ideas. Throughout this project, they learn about the biology behind different communicable diseases. Because students are asking questions that can be connected to their personal health, they begin to ask questions about their own health and how their actions can directly affect it.

The driving question of this project leads students to investigate different infectious agents, the various mechanisms by which their body can ward off disease and how they can affect the spread of disease. When students look more closely at the agents that can cause disease, they investigate biological relationships that affect the spread of disease.

Actively engaging with phenomena facilitates students' understanding. During the project, students ask question, conduct experiments and draw conclusions. Learning is supported through the construction of models about the spread of disease. Students us Model-It, a dynamic modeling tool, to construct models of how a disease can spread through a population. Students draw on hands on investigations using Thinking Tags, a learning technology developed at the MIT Media Laboratory, or the Palm Pilot Cooties application to create their computer generated models. As students' understanding grows, so do their models. Students continually plan, build and test their models based on their understanding.

The community component of this project is maintained through the involvement of community members, both parents and experts and the use of articles from local newspapers and the Internet.

At the conclusion of the project, students construct a final artifact. Students choose the format and the focus of their artifact at the start of the project and develop their individual project, the Disease Investigation, throughout the 8 week long unit. The Disease Investigation, guided by a rubric, is developed using material created throughout the unit by the students in the different investigations. Using Model-It or other available technologies, students present their findings about their Disease Investigation to the class or a larger community group.

Upon completing the unit, students should be able to describe different infectious agents and explain how the human body protects itself from disease. Students should be able to describe how these agents can enter the body and how the infectious agents can be stopped. Specific knowledge about different STDs will be gained from this unit.

Special Unit Concerns

Because this unit covers different sexually transmitted diseases, care needs to be taken in discussing these diseases. Teachers need to observe district and state policies concerning these topics. Parents need to be notified that these topics will be covered and they have the option of viewing the curriculum, observing the class or removing their children at no penalty to the student. In addition, additional training of the teacher will be required after the pilot stage of the unit.

Learning Set One:
Is anyone sick?

Overview

In this activity, students are introduced to how a disease can spread through a population without any physical symptoms. This activity illustrates that their good friends can in fact make them sick. This activity leads into a study of the biology behind communicable diseases. A range of communicable diseases are introduced in the class discussion following this activity. Sexually transmitted diseases need to be introduced in this initial contextualization activity and discussion. This activity serves as an initial anchoring activity that is returned to throughout the unit as students develop their understanding of disease and how their body defends against disease.

Purpose

- Introduce the driving question.
- Generate student interest.
- Elicit students' personal experience with disease and how disease can spread.
- Give students a common anchoring experience.

Learning Set 1 Calendar

Learning Set 1
Is anyone sick?

Session 1 Are you sick? Setting the context for the unit	Day 1 Introduce the Driving Question Set up and do Spread of Disease activity using liquids Reader: Tracking an outbreak
Session 2 What is a disease?	Day 2 Class discussion and written reflection Introduce the goals of the unit Concept map of what a disease is Reader: Introduction of individual diseases (sexually transmitted diseases included) Day 3 Discussion of the concept maps and of the reading material Modification of concept maps

Major products for teacher assessment

Participation in the class activity, classroom discussion and journal entries can all provide materials for teacher assessment. In addition, the concept map created on day 3 allows for the teacher to assess the initial understandings of the students about disease.

Introducing the Driving question

The driving question is introduced through personal experiences of students. The initial spread of disease activity is used to create a common experience between the students in the class. Students then reflect on their own experiences with being and getting sick and share their stories with the class. Real experiences of students are brought into science as students offer an initial explanation of why the event occurred as it did.

Spread of Disease Activity

In this anchoring event, students experience how a disease can spread through a population without any physical evidence. This activity will be modified and used later in the project so students can apply the biological concepts that they learn to determine how and why a disease can spread through a population. By returning to this event several times during the unit, students will develop an understanding of the biology behind disease and ways to prevent the transmission of specific diseases.

Asking questions and defining what a disease is.

Here students begin to think about what information they will need to be able to answer the driving question. They begin to form questions that will lead their inquiry into disease and think about designing their own disease investigation. They begin with reviewing what they know about disease and agreeing on a way to talk about the biology behind disease in this unit.

Concept map of what is disease

A concept map is a teaching tool that gets at what the students' understanding is of a particular concept or group of concepts. On a typical concept map, each concept is represented by a representative word in a circle. These circles are then linked together with lines and linker words that help develop the understanding or explanation of the concepts. These linker words create sentences with meaning. Linker words can be simple or complex. Concept maps can be arranged in hierarchical structure—general concepts at the top, developing in complexity as one goes lower, or they can be more web-like with the general concept at the center of the web. Students should be allowed to develop a map as they want, as long as they can give an explanation of what they did and why.

Session 1:
Are you sick? The spread of disease

Overview

The driving question "How can good friends make you sick?" is introduced to students through personal experiences with the spread of disease activity. Students participate in the spread of disease activity to create a common experience. This anchoring activity leads to a class discussion about how a disease can spread through a population and what a disease is. In this discussion of the activity, students are asked to share their own experiences with disease and to draw from the initial reading of a description of a real disease outbreak. Students begin with familiar experiences from real life settings to think about the biology of disease. By the end of the session, students will have been introduced to the spread of disease activity, a description of an epidemic, and the goals of the unit, and they will have developed an initial concept map of what a disease is. Students should be able to explain in descriptive terms how a disease can spread through a population with no obvious evidence.

Purpose

- Introduce the driving question.
- Generate student interest.
- Give students a common anchoring experience.
- Elicit students' personal experience with disease.

Session Preparation

- Carry out the spread of disease activity so that you are familiar with how the activity should go.
- Post the driving question in the classroom.

Learning Set 1 Session 1 Calendar

Pre Session 1	Session 1 Day 1
Introduce the Driving Question Assign initial reading assignment from the student reader	Introduce the Driving Question Set up and do Spread of Disease activity Class discussion about the spread of disease

Materials

- Classroom set of containers: test tubes or plastic dixie cups work well
- Distilled water
- A dilute basic solution: A dilute solution of sodium hydroxide (0.1M NaOH) or a solution of baking soda in bottled water (30-40 teaspoons of baking soda in 2 quarts of water)
- pH indicator: Phenolphthalein pH indicator or water from a blended red cabbage can be used.

Preparing for the activity

Basic solution: If using the baking soda solution, dissolve 30-40 teaspoons of baking soda in 2 quarts of water. Care should be taken to get as much of the baking soda into solution as possible, this can be done by either stirring or shaking the solution. When using the solution, let the undissolved baking soda settle to the bottom so that the “disease source” looks the same as the other cups of water. Students should not know that there are two solutions present.

pH indicator solution: if using the red cabbage water, either boil a cut up cabbage for 15 minutes and then collect the water or blend the cabbage in a blender with distilled water and strain, collecting the liquid. Refrigerate both solutions until ready for use, if the solutions will not be used for several days, freeze until ready to use.
If using the phenolphthalein indicator, use only a drop per dixie cup during the test phase. Care should be taken when using this solution as it is a hazardous solution. Refer to the packaging of the solution for proper handing procedure.

Set up for the activity before class

Set up a classroom set of containers, all filled with water except one which is filled with the basic solution (either the baking soda solution or the 0.1 M NaOH). The container with baking soda or 0.1 M NaOH serves as the disease source. There should be no visible difference between the water and the basic solution. Fill only 1/4 of the way to keep from spilling.

Hand out cups to students and allow students to share the liquid when you instruct them to start the activity.

Safety issues

If using the NaOH solution and the phenolphthalein indicator, instruct the students not to drink the solutions as they are harmful and to immediately wash with soap and water if any solution is spilled on their hands or clothing. Students should use eye goggles if using the NaOH solution and phenothphthalein.

SESSION 1 Introduction

Introduction of the Communicable Disease Unit

This introduction serves as a pre-activity before the main contextualizing activity of the unit.

Introduce the Communicable Disease Unit by explaining to the students that they are going to be investigating the driving question How can good friends make you sick?

- Have the students respond to this question—
  - Do they think that friends can make them sick?
  - Is it necessary to for people to be friends to make each other sick?
  - What do they think about this question?

In order to find out the answers to these questions and the larger driving question, they are going to be investigating a number of different diseases and doing a series of investigations. To start off this unit, they need to read an initial description of how a disease was tracked.

Pass out the initial reading assignment from the student reader.

Have the students read this before starting the first session. This reading material will help give context to the spread of disease activity and will introduce the students to the idea that the spread of disease can be traced and that people do this for a living.

SESSION 1/ DAY 1

Spread of Disease Activity

Introduction

Introduce the spread of disease activity by asking students to think about the last time they got sick. Questions that might be used to get the students thinking about when they were sick could include:

- Have they had the flu this year? Have they been sick?
- Did they know who got them sick? Why or why not?
- Who can get sick?
- Other questions can be used as well.

Ask for two or three students to respond to these questions.

Ask the students to respond to the reading that they did the previous night

1. What was it about?
2. What did they think about it?
3. Did it make them think of any questions that they wanted to answer?

Tell the class that they are going to do a short activity about the spread of disease. This activity will illustrate what they read about and what they have experienced in the past when they have gotten sick. After the activity, they will discuss more about the spread of disease and what disease is, so they should keep these ideas in mind while doing the activity.

These initial stories and explanations not only serve as vehicle to bring the students' experience into the science classroom they also are the beginnings of the artifact that will be created in this project.

The biology of disease is made meaningful to students by beginning with discussion of their own personal experiences with disease. This helps to connect concepts that will be learned in the classroom to biology as it happens in the real world.

Connections need to be made between the reading that the students did and the spread of disease activity.

Do not tell students that a disease source is present in the spread of disease activity.

Spread of Disease Activity

1. Hand out a container to each student; caution the students not to spill the solution. If it does spill, have the students wash immediately with soap and water.
2. Have the students carefully share liquids with one another. Mixing should be done with pairs of students. Students can pour the solutions into one container, mix and return half to the original container. Students should always have the same (or close to the same) amount of solution that they started with after mixing with a classmate.
3. Have the students ask each other questions before or while they are sharing. This will serve to slow the students down and to allow them to interact as they might in a real world situation. In addition, answers can often serve as examples of how a disease can spread. Possible questions to ask:

   What is your favorite after school activity?
   What is your favorite subject?

This spread of disease activity and the class discussion will be an anchoring experience for students to think about as they develop understanding of the underlying biology concepts

Students need to be cautioned to handle things with care and that they should wash hands following the activity. Care needs be taken so that no liquids are spilled

4. Remind students that mixing solutions is their choice; they can interact with as many or as few students as they want.
5. After sharing and mixing solutions with different students, have the students return to their seats.
6. At this point, tell them that a contaminant or disease had been identified in the population that they represented. This contaminant might be found in some of the containers and through their mixing activities it might have spread though the population.
7. Tell the students that a test exists to see if they have been infected. This test will show a color change with the addition of a second indicator solution if the contaminant is present.
8. Now add the pH indicator (red cabbage juice or phenolphthalein) to the mixed solutions. If using the red cabbage juice, an uninfected individual's solution will turn purple/red, (the color of dilute cabbage juice) and an infected individual solution will turn green or greenish blue. A range of green color might be seen, indicating how diluted the infecting agent became in the activity. If using phenolphthalein, an infected solution will turn red-pink and an uninfected individual will stay clear. Use a dropper so that only a small amount of indicator is used.

on either hands or clothing.

If using the baking soda and cabbage juice solutions, the color change will not be as dynamic and shocking for the students, but differences will be detectable.

Use caution if using the phenolphthalein solution, if possible have the students place the cups containing the solution in a safe area that they can see but not touch. Phenolphthalein is a potential tetratogen and comes with a caution for use.

Have the students discuss what they did and what they learned. How has the activity added to what they know about the spread of disease. Questions that might be raised include:

- Who might have started the disease? Do they know for certain? Why or why not?;
- How can you tell if someone has a communicable disease?;
- What is meant by a "communicable disease"?;

If students don't know the word communicable, ask them what communication means and how it might be related to communicable

- Can you always tell if someone has a communicable disease?
- How can a communicable disease be stopped?

Continue the activity by having students write down whom they shared fluids with and in the order that they shared. From this information, the source of the disease can be traced, but only if the students remember correctly. The results for such investigations are only as good as human memory and this is exactly how real epidemics are traced.

Building community: Try to encourage students to address each other directly rather than always respond to your questions.

After the activity, allow students to comment on what they did and what their feelings were about the activity. Again, encourage students to address each other when they share their ideas.

Re-introduce the project "How can good friends make you sick?"

Tell students that in this project they are going to think about diseases and how diseases are caused. They are going to answer the question of "How can good friends make you sick?"

Explain to the students that they will be investigating how friends can

The introduction of the driving question will serve to connect the contextualizing activity make friends sick by looking at the biology behind communicable diseases, these diseases will include sexually transmitted diseases.

to the rest of the unit. Students will return to the driving question throughout the unit.

The project will be eight weeks long and they will do a series of investigations using lab materials and computers. They will be creating the questions and finding the answers through their own investigations.

Introduce the use of project notebooks—students will have lab notebooks in which they will write their thoughts, investigations and anything else that they think of during the whole unit. They will use this lab notebook like scientists use their notebooks.

By having the students write this initial description of their experience with disease in their journals, they will have this to return to as they develop a more scientific understanding of disease.

Have them respond to the driving question: “How can Good Friends make You Sick?”

Have the students write their initial understanding about how diseases can be spread through a community in their notebooks.

Students' initial explanations will likely not be very scientific at this time. Their explanation will probably also be very sketchy and terms may be used incorrectly.

Have students share what they think about doing this type of project and what they think of the question.

Wrap-up

Have the students discuss

- Their responses to the questions that they wrote in their notebooks.

Additional questions could include:

- How will this spread of disease activity help answer the driving question?
- How does the reading that they did apply to the real world?
- What other disease can they think of that might apply to these types of scenarios?

This can be done in either small group settings or in a larger class discussion. If done initially in small groups, have the small groups join the larger class discussion and share what was talked about.

Meaning Making is crucial for the students—through internalizing and talking about what has happened students will begin to understand and retain the material being taught.

Assign Homework

Have the students read the initial section in the Student Reader about tracking diseases and the initial introduction to their specific disease that they will be investigating throughout the unit.

Student reader Pages 2-3