

# **Reforming Science Education through University and School District Collaborations**

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## **Introduction**

Inquiry is an essential component of science. NRC (1996)(National Research Council 1996) argues that inquiry into authentic questions generated from student experiences is the central strategy for teaching science. Teachers focus inquiry predominantly on real phenomena, in classrooms, outdoors, or in laboratory settings, where students are given investigations or guided toward fashioning investigations that are demanding but within their capabilities. Technology can play a central role in implementing those standards. The new computational and communications technologies afford students an opportunity to engage in serious inquiry.

Several programs have been developed that stress inquiry, yet there are few in depth descriptions of students as they engage in inquiry, especially during the difficult periods of their initial attempts (Marx, 1997; Roth, 1995)(Roth 1995; Marx, Blumenfeld et al. 1997). Few descriptions of how young urban students engage in this process have been written.

Our research group at the Center for Highly Interactive Computing in Education (hi-ce) has been creating new instructional environments that foster new kinds of learning. Over the past 10 years our group has created a research and development agenda to support reform in science education with particular emphasis on the use of powerful learning technologies. We have worked with teachers to develop project-based science curriculum and pedagogy and learner centered technologies to support inquiry. This innovation, one member of a family of constructivist teaching and learning approaches, is in keeping with recommendations by the American Association for the Advancement of Science (AAAS) and the National Research Council (NRC). Currently, we are involved in a reform effort in collaboration with the Detroit Public Schools' Urban Systemic Program in Science and Mathematics and the Center for Learning Technologies in Urban Schools, both supported by the National Science Foundation (NSF). The goal is to make inquiry-based science supported by pervasive technology tools the basis for all middle school science in the district.

## **Purpose**

What students learn and how they engage in inquiry supported by technology are important to understand in order to promote science education reform. Some might argue that widespread enactment of a project-based curriculum in urban settings is not possible because students are not likely to have the skills to engage productively in the process. Thus the purpose of this paper is to describe how urban students performed on pre and

post-tests in 4 different inquiry-based and technology rich curriculum units. In this paper we first describe our work in curriculum and technology development, and professional development. Next we describe our collaboration with the Detroit Urban System Program. We then describe our methods and report our findings. Finally, we ----

## **Our Innovation**

In working towards systemic reform, our research group joined with the Detroit Public Schools in implementing an innovation comprised of a number of interlocking components, curriculum, technology, and professional development. Many of these components were products of the previous work by the Center for Highly Interactive Computing in Education, but others were new creations or adaptations developed collaboratively with the Detroit administrators and classroom teachers. The challenge was to take work that had successfully fostered learning in the context of a number of design experiments and attempt to bring it to a large-scale urban and systemic context. Below we present an abbreviated description of the components of our innovation, in order to provide a context for understanding the discussion that follows of the challenges it presented for systemic reform.

### ***Curriculum and Pedagogy***

Our work is rooted in inquiry pedagogy that is consistent with constructivist ideas (Blumenfeld, et. al, 1991). The presumption is that students need opportunities to construct knowledge by solving real problems through asking and refining questions, designing and conducting investigations, gathering, analyzing, and interpreting information and data, drawing conclusions, and reporting findings. We refer to this process as project-based science (PBS; Blumenfeld et al., 1994, Krajcik, Czerniak, & Berger, 1998)(Blumenfeld, Krajcik et al. 1994; Krajcik, Blumenfeld et al. 1998). Together with Detroit, we have developed four middle school science units: a sixth grade unit on mechanical advantage, seventh grade units on air quality and water quality, and an eighth grade unit on force and motion (Singer, Krajcik, & Marx, 2000). Our eventual goal is to develop enough units to comprise an entire middle school science sequence.

Based on principles of social constructivism which are active construction, consideration of prior experiences, situated cognition, community and discourse, we developed engaging curricula, which address everyday life, deal with real life settings, promote inquiry supported through technology and collaborative work in project-based science. Each unit is built upon national, state, and most importantly, local district standards. Our curriculum units are designed to last between eight and twelve weeks. Each includes: a) a driving question, encompassing worthwhile content that is meaningful to students and anchored in a real-world problem; b) investigations and artifact development that provide opportunities for students to learn concepts, apply information, and represent knowledge around the driving question; c) collaboration among students, teachers, and others in the community; and d) use of computational technological tools to promote inquiry. In addition, the curriculum materials include benchmark lessons that help students learn difficult concepts, illustrate important laboratory techniques, or develop investigation strategies (Krajcik, Czerniak, & Berger, 1998(Krajcik, Czerniak et al. 1998)). Furthermore, the curriculum materials themselves are intended to be “educative” for teachers (Ball & Cohen, 1996)(Ball and Cohen 1996), providing opportunities to learn

about new teaching practices, content and classroom enactment from the materials themselves.

**Curriculum Principles.** The curriculum we have developed have been based upon the following principles:

- **Context** is created through the use of driving question, based on real world experience, and the use of anchoring events, which expose students to phenomena under study.
- **National standards** (AAAS, 1993; NRC, 1996) specify the sequence and substance of science concepts, specialized language, and practices and methods for asking questions, solving problems and analyzing data. Standards also claim how to help learners understand the nature of science, advocating a pedagogical approach that promotes the active construction of knowledge.
- **Inquiry** allows students to ask questions, plan experiments, and collect, analyze and share information. Inquiry also allows students to experience scientific phenomena and processes and to create new information.
- **Collaboration and student discourse** is fostered within the learning community. Students are encouraged to work in groups, discuss their investigations, share their knowledge, and create group presentations.
- **Learning tools** are used by students to support various aspects of inquiry. Learning technologies within the projects mirror those used by scientists, but are designed with learners in mind «Krajcik, in press #14; Jackson, 1999 #13».
- **Artifacts** are created as students conduct investigations. Students create artifacts that can be shared, critiqued, and revised to further enhance understanding and serve as a basis for assessment.
- **Scaffolds** are designed to help guide learning as students are introduced to science concepts and processes. Teachers sequence, model, coach, and give feedback. Learning materials reduce complexity and highlight concepts and inquiry strategies. Technology provides multiple representations, hides complexity, and guides processes.

### ***Software Tools***

In conjunction with PBS pedagogy, we have developed a set of computational tools to support and scaffold inquiry based upon principles called learner centered design (LCD; Soloway, Guzdial, & Hay, 1994). LCD is founded on the idea that learners are a unique class of computer users, and thus require special forms of support from software interfaces in order to complete their tasks successfully. Furthermore, the tools can be used over and over again throughout a student's academic career in different science classes.

The Investigators' Workshop<sup>1</sup> is a suite of computational tools we developed to enable sustained inquiry (Krajcik, Blumenfeld, Marx, & Soloway, 2000; (Krajcik, Blumenfeld et

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<sup>1</sup> The development of the Investigators' Workshop has been supported by grants from the National Science Foundation: (NSF Grant numbers REC 9554205 and REC 955719)

al. 2000) Soloway & Krajcik, 1995). These tools support data collection, data visualization and analysis, dynamic modeling, planning, information gathering from the UM digital library, the Internet and web publishing (Jackson, et. al., 1994; Krajcik, Blumenfeld, Marx & Soloway, 2000; Wisnudel et. al, 1997)(Wisnudel, Stratford et al. 1997)ww. Some software, like ModelBuilder, is designed for use at single computers, which do not need to be networked. Others use the Internet, such as Artemis, which is a front-end to a digital library tailored to young learners (Wallace, Kupperman, Krajcik, & Soloway 2000)(Wallace, Kupperman et al. 2000).

### ***Professional Development***

To help teachers appropriate and learn how to use the innovations introduced in this work, we rely on a conceptual framework for professional development we call CERA (Krajcik, Blumenfeld, Marx, & Soloway, 1994)(Krajcik, Blumenfeld et al. 1994), which stands for Collaborative construction of understanding; Enactment of new practices in classrooms; Reflection on practice; and Adaptation of materials and practices. CERA provides the general backdrop for our collaboration with the school district and with teachers in all activities, including professional development. Professional development is conducted throughout the year in activities ranging from a two-week summer institute to Saturday work sessions, and including classroom support from both district and university personnel. The implicit goal for the design of our professional development activities is to provide opportunities for teachers to enhance their knowledge, beliefs, and attitudes about science content, science teaching, and technology use (Fishman, et al., 2000)(Fishman, Best et al. 2000)

### ***Approaches to Professional Development***

- Summer Institute
- Saturday Workshops
- Technology and Administrative Support
- In-Class Support
- Educative Curricula

### **Standards-based Curriculum**

We have developed and enacted five middle school curriculum projects using the curriculum and pedagogy principles described above.

- **Communicable Diseases – Eighth Grade:** The Communicable Disease Project explores the questions: Can good friends make me sick? This driving question is used throughout the unit to tie the biology the students are learning to a larger issue that directly affects them. Throughout this unit, students learn crucial biology behind different communicable diseases, including the immune system, disease transmission, and sexually transmitted disease. Students use a variety of technologies including modeling software, digital library resources, and simulation tools (smart badges).
- **Force and motion —Eighth Grade:** Designed for use in eighth grade, students explore the question “Why do I need to wear a bicycle helmet?” Through the exploration of this question, the learner develops an integrated understanding of Newton’s laws of motion, force, velocity, and acceleration, and the relationship

among force, mass and acceleration in the context of being pitched off their bike, getting injured, and learning how helmets work. Technology use includes probeware.

- **Basic Chemistry Principles—Seventh Grade:** This air quality curriculum unit engages 7<sup>th</sup> grade students in an extended inquiry into the question “What is the air like in my community?” This inquiry provides students with a rich and meaningful environment to conduct investigations, learn relevant science content, and develop understanding of an environmental issue, air quality. In the context of learning about air quality, the learner develops an integrated understanding of science concepts such as composition of air, states of matter, chemical versus physical changes, chemical reactions, acids and bases, atoms, elements, compounds, and mixture. Technology includes probeware and modeling software.
- **Water Ecology—Seventh Grade:** The water ecology project engages 7<sup>th</sup> grade students in an extended inquiry into the driving question “What is the quality of water in our river?” In the context of learning about water ecology, learners construct an integrated understanding of science concepts such as ecosystems, watersheds, rivers, biodiversity, macroinvertebrates, biotic index, bio-indicators, topography, and various water quality tests, such as fecal chloroform, pH, and dissolved oxygen. Students use probeware, World Wide Web and computer modeling tools.
- **Simple Machines – Sixth Grade:** Designed for 6th grade students, the project explores the question “How can I move big things?” The learner develops an integrated understanding of applied and resisting forces, the types and workings of the six simple machines, and mechanical advantage, in the context of exploring how machines help people build large structures. The project integrates the use of probeware (i.e., force and motion probes).

## **Collaborations with Detroit’s Urban Systemic Program**

In the past two years, with support from NSF and the Spencer Foundation, and in conjunction with the Detroit Urban Systemic Program, we have extended our work on the development of curriculum, learning technologies, and professional development into an entirely new type of learning environment—a large urban school system. With change has come a broader change in focus, to the challenges of scaling, sustainability, and the building of capacity and capability for all teachers and students in Detroit Public Schools.

Our approach to reform is one of collaboration, not technology transfer. As such, we are sensitive to the context of the reform (Fullan & Miles, 1992). Rather than simply impose change from the outside, we emphasize process, collaborating with teachers and administrators to adapt the innovation so that it is achievable given the constraints of the context, but also true to the underlying premises of the instructional approach. Simultaneous attention to and coordination of several elements—curriculum, pervasive technology, professional development, policy and management, assessment, and community involvement and their interaction—is imperative so that in combination they support the innovation (e.g., Newman, 1992)(Newman 1992). Moreover, coordination of administrative and organizational rearrangements required by the innovation also is crucial. Only then will urban systems like Detroit develop the capacity, capability, and

culture necessary to cope with the complexities involved in adopting and sustaining curricular and technological change.

Our prior work with schools involving inquiry supported by technology was done with individual teachers in both urban and suburban schools serving children from different social class backgrounds. We think that it takes teachers about three years to become proficient in this approach and about the problems that teachers face while doing so (Blumenfeld et. al, 1994)(Blumenfeld, Krajcik et al. 1994). We also have described building level challenges such as resource allocation and scheduling Blumenfeld et al., in press).

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Our current experience that involves systemic scaling has posed new challenges that affect enactment of our curriculum and opportunities for students to learn. Professional development efforts have been impacted by collective bargaining agreements that require payment for any additional time teachers spend after school and prior notification of those attending meetings. This makes scheduling of meetings difficult and establishing informal teacher networks and workgroups in schools quite difficult. In addition, because of teacher shortages, even though there are funds for released time, teachers often are not free to attend meetings because they must cover for other absent colleagues. The teacher shortage also means that many individuals are teaching out-of-field and are not prepared to teach science.

	Standards Based Curriculum	Policy Infrastructure	Professional Development	Pervasive Technology	Community & Family Engagement
Standards Based Curriculum		<ul style="list-style-type: none"> <li>• Alignment of curriculum &amp; assessment</li> <li>• Resources</li> <li>• Schedule issues</li> </ul>	<ul style="list-style-type: none"> <li>• Content</li> <li>• Pedagogy</li> <li>• Beliefs</li> <li>• Educative curriculum</li> </ul>	<ul style="list-style-type: none"> <li>• Re-usable tools</li> <li>• Broadly applicable</li> <li>• Matched to problem at hand</li> </ul>	<ul style="list-style-type: none"> <li>• Culturally responsive</li> <li>• Community participation</li> <li>• Authentic problems</li> <li>• Community expertise &amp; resources</li> </ul>
Policy Infrastructure			<ul style="list-style-type: none"> <li>• Time &amp; contract issues</li> <li>• New roles and recognition</li> </ul>	<ul style="list-style-type: none"> <li>• Maintenance</li> <li>• Acquisition</li> <li>• Distribution</li> <li>• Security</li> </ul>	<ul style="list-style-type: none"> <li>• Accessible schools</li> <li>• School governance</li> </ul>
Professional Development				<ul style="list-style-type: none"> <li>• Dial-in support for teachers</li> <li>• Professional learning networks</li> </ul>	<ul style="list-style-type: none"> <li>• Understand community</li> <li>• Frequent communication</li> </ul>
Pervasive Technology					<ul style="list-style-type: none"> <li>• Affordable &amp; accessible technology</li> <li>• Culturally responsive</li> </ul>
Community & Family Engagement					

**Table 1.** A framework of factors critical to urban systemic reform.

Similarly, some district policies work against doing long term inquiry. For example, in the current era of increasing importance of test results, the schools spend considerable time preparing students for state standardized tests, so that almost a month in the winter is unavailable for instruction. Later in the year several weeks are devoted to city-wide administration of national standardized tests. In addition, time is devoted to creating science fair entries, which currently are not related to the inquiry curriculum.

In addition, the pressure to raise test scores means that supervisors and principals are not equally supportive of our efforts, despite the active endorsement and participation of the central administration in working with principals and collaborating in curriculum development. The result is that some teachers are encouraged to intersperse lessons from other sources into the project-based curriculum or to spend less time on inquiry and more on traditional textbook based instruction.

District policies and practices also mitigate against effective technology use. To date differences in building level practices means that distribution and scheduling make access

to computers during science instruction difficult in some schools. Maintenance policies are centralized so that teachers cannot be assured that the equipment will be functional; responses to requests for assistance often take a long time. In addition, there has been considerable difficulty in establishing reliable Internet connectivity due to difficulty with accessing high-speed lines and concerns about security. As a consequence, many teachers are hesitant to use the technology because they anticipate problems, even though those that have tried discover that students are able to learn the software quite quickly. In buildings where teachers are dedicated to this approach and have the technological capability to keep the equipment running smoothly, there has been more success in exploiting the benefits of learning tools.

As a result of our experiences and our collaboration with Detroit administrators and personnel, both groups are trying to find solutions to these problems by adapting the curriculum, changing professional development activities, and altering technology and other practices to create conditions that will facilitate successful curriculum enactment and promote student learning.

Obviously it will take time for these challenges to be resolved and certainly what we learn can be helpful to others trying to engage in systemic reform. Right now our efforts can be considered a "work in progress" where all elements are in flux. Nevertheless it is encouraging to examine pre- and posttest results from each curriculum. They show that despite the problems outlined, there are consistently significant improvements in student learning across curriculum.

## **School/University Partnerships**

Leveraging the talents and expertise of practitioners and researchers

Researchers bring

Focus on Theory

Innovative learning technologies

Practitioners

Knowledge of local context

Specific needs of their students

Day to day class realities

Results in

Theory based, technology infused curriculum that responsive to the day to day needs of schools, teachers and students

## **Impact**

The LeTUS curriculum projects have impacted over 4,000 students yearly across the middle grades. Table 1 shows the number of students and teachers using LeTUS curriculum in the 1998 – 1999 and 1999-2000 school years.

**Table 1: Curriculum Implementations—Number of Teachers and Students Impacted**

Curriculum	Grade	When	Teachers	Students
How Can I Building Big Things? (Mechanical advantage)	6	Fall, 1999	2 (pilot)	210
Why Do I Need to Wear a Bike Helmet (force and motion)	8	Fall, 1998	3	110
		Fall, 1999	8	750
What is the Quality of Air in My Community? (air quality)	7	Fall, 1998	9	627
		Fall, 1999	9	900
What is the Quality of Water in My River? (water quality)	7	Spring, 1999	10	615
		Spring, 2000	12	1200
Can Good Friends Make Me Sick? (communicable diseases and the immune system)	8	Spring, 2000	1 (pilot)	30

## **Conclusion:**

The collaborative effort between the Detroit Public Schools and the University of Michigan provides several key components for effecting change in the learning of science in urban schools. Collaboration with teachers and administrators allows for: 1) a high level of relationship between the created curriculum materials and learning goals of the district, 2) a means to rapidly develop curriculum materials and personnel which coincide for the pedagogical call for learning through inquiry, 3) the utilization of the pedagogical content knowledge of practicing teachers and 4) materials to be tailored to the needs of specific populations, in this instance urban middle school students. Despite these benefits, utilizing this collaborative approach has challenges. One such challenge is establishing and maintaining numerous relationships between and among university personnel, district and building administrators, and classroom teachers.

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