

Curriculum Revision as a Research Activity: Using Classrooms to Improve Curriculum

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Abstract

As part of our effort to design curriculum materials, we report on a systematic research method for improving materials based upon learning goals, and adaptability and usability. Our work is with an ongoing urban systemic initiative of a large public school district to reform science and mathematics education, and our science curriculum materials are consistent with constructivist ideas and addressed national, state and local goals for student learning. If curriculum materials are to be a vehicle for reform, however, they need to be effective in classrooms on a large scale. Few have reported methods of classroom research to improve materials. We are interested in not only students' ability to use materials to achieve important learning goals, but how the materials are usable by teachers and adaptable to differing classroom situations. We found that a variety of sources needed to be explored in systematic order and then integrated to gather meaningful information on which to base revisions. Each source gives valuable insight, but only in light of the other sources, the goals for revision, and underlying theoretical principles. In addition we found that the need for revisions based on usability and adaptability was more evident in large scale enactments beyond initial pilot testing. We believe that a method of classroom research can be defined that supports real curriculum improvement and informs efforts to create future curricula.

Objectives

The goal of this study was to describe method for improving curriculum materials. Our work was embedded in an ongoing urban systemic initiative of a large public school district to reform science and mathematics education. As part of this effort to reform education, science curriculum materials were developed that were consistent with constructivist ideas and addressed national, state and local goals for student learning. Creating innovative curriculum materials, however, is not enough. If curriculum materials are to be a vehicle for reform they need to be effective in real classrooms with real teachers on a large scale. We were interested in designing a method for revising the curriculum materials that focuses not only on students' ability to use the materials to achieve important learning goals, but if the materials are usable by teachers and adaptable to a variety of classroom situations. In this paper, we describe a method of utilizing classroom research to support justified curriculum revisions in light of current theories about learning.

Rationale

Recent reforms in science call for curriculum designed to embody social constructivist learning theory by supporting students' construction of knowledge through inquiry supported by technology tools (American Association for the Advancement of Science, 1993; National Research Council, 1996). There are several ongoing initiatives aimed at creating curriculum materials to reform science education (i.e., the Cognition and Technology Group at Vanderbilt's (1992) Scientists in Action, Linn's (1998) Computers as Learning Partners, and Songer's (1993) Kids as Global Scientists). Likewise, we have developed curriculum materials based on principles that are consistent with what is known about teaching and learning. These include: contextualization, alignment with standards, sustained student inquiry, embedded learning technologies, collaboration and discourse, assessment techniques, and scaffolds and supports for teachers. Appendix A summarizes the relationships among the seven design principles, the social constructivist features, and the rationales that unite the principles and features (Singer, Marx, Krajcik & Chambers, in press). Curriculum materials created by using these design principles can promote deep understanding of science concepts and inquiry strategies and address the needs of diverse students (Krajcik, Blumenfeld, Marx, & Soloway, 1999).

However, methods of revision to improve materials have not been frequently reported. Some groups have published and discussed their methods of curriculum design and development (e.g. Krajcik, Blumenfeld, Marx, & Soloway, 1999; Linn, 1999; Sherwood, Pertosino, Linn, & Vanderbilt, 1998). Fewer have discussed their process for revising curriculum materials based on enactment data. One example of a project that has dealt with revision issues is the Computers as Learning Partners project (Linn, 1993). The CLP project worked to refine a thermodynamics curriculum in a model classroom with intensive intervention support. This group made yearly revisions on a middle-school thermodynamics curriculum unit over the course of 10 years, based on student performance on pre- and posttests and limited student interviews. Gains in student

learning and beliefs about science were achieved through these revisions over the course of the project. As of yet, however, there has been no discussion about how to revise and improve curriculum materials to address students' content and process understanding in a variety of classroom settings. We have only speculative knowledge as to why many wonderful curriculum ideas fail to be realized in classrooms beyond the initial implementations (Brown, 1992). In order to address this issue we present our methods of revising and improving curriculum materials that are currently being enacted in a variety of classroom settings. . We feel that it is important to analyze the use of materials in these settings to improve theory-based curriculum materials.

If curriculum materials are to facilitate reform they must also support the transition to new practices by a variety of teachers in a variety of classroom settings. Enacting reform-based curriculum is not easy. We know that attempting to enact inquiry-based curriculum presents many challenges to teachers and they will need support. Specifically we know that Project-based Science curriculum presents several challenges to teachers (Marx, Blumenfeld, Krajcik, & Soloway, 1997; Scott, 1994). Teachers will need support in this transition, yet those participating in large urban reform will likely have less one-on-one support by researchers and school personal than those teachers who voluntarily participate in reform programs. This puts an addition pressure on the materials to take an active role in supporting reform efforts. We have designed our materials to support and scaffold teachers in learning content and pedagogy (Schneider, 2000; Middleton & Schneider, 1999; Ball & Cohen, 1996). In order for reforms to be realized it becomes important to look beyond student learning to also address issues of use and adaptation of the materials by a range of teachers and in different classrooms. We strive for our materials to be usable by teachers, in that we intend for teachers to be able to translate curriculum materials into practices that instantiate inquiry in their classroom. In addition, for reform-based practice to become integral in a variety of classrooms the materials must also be adaptable, so that teachers can make them their own to meet the unique need or context of their classroom, again while maintaining integrity of materials as inquiry. We feel that it is important to consider these aspects of classroom enactment as well as student learning as we attempt to improve curriculum materials.

We have outlined a complex curriculum revision agenda, in that we have charged our curriculum materials with the task of playing a critical role in urban science education reform. Not only must our materials support student learning of important science content through inquiry, the materials must also support teachers in transitioning to inquiry practices that meet the special needs of their unique classroom setting. Although only classroom based research will help us to begin to look at these issues, this method also increases the complexity of the revision process. Classrooms are complex settings that will require new and complex methods for research (Brown, 1992). In this paper we describe our method of using classrooms to justify revisions in curriculum materials that are consistent with educational theory. This is an important discussion if curricula are expected to succeed in classrooms beyond the control of the design and research group.

Background

In this study we examined curriculum materials for their success in 1) supporting student learning, 2) usability by teachers to enact inquiry based practices, and 3) adaptability by teachers to meet the needs of their students. We collected and analyzed data from a wide variety of sources as we focused on these three aspects of curriculum materials. We also repeated this process across several curriculum units. As we searched for evidence on which to base our curriculum revisions we also examined our process of collecting and utilizing different sources of information and how each informed revision decisions in light of educational theory.

Context

This study was conducted as part of our work for the Center for Learning Technologies in Urban Schools (LeTUS). LeTUS is a joint partnership with the University of Michigan, the Detroit Public School System, Northwestern University, and the Chicago Public School System. The goal of the Center is to infuse the use of effective learning technologies in urban Detroit and Chicago schools at a systemic level. In order to accomplish this goal, the Center utilizes the framework of project-based science (PBS), using a combination of custom-developed curricula, innovative technologies, and intensive professional development for middle school science teachers in these urban settings.

Among other issues, we found that the school system needed appropriate curricula to most effectively use innovative technologies to support learning. Therefore, we took as part of our mission of systemic change the development of curriculum projects. These projects are guided by seven design principles that draw from ideas about thinking and learning related to social constructivist theory. Our design principles are described in appendix A.

Developing Curriculum

Currently LeTUS has five curriculum units, or what we call ‘project’, in different phases of development and revision. Each of our curriculum projects is developed using the same general process. Initial design and development takes place within curriculum-specific work circles consisting of teachers, university educators and researchers, and content experts. Initial development takes place in several steps. First, using national and local standards and curriculum frameworks, work circle teams of teachers, university educators, district administrators, and content specialists map out the content coverage and appropriate presentation of ideas and representations. Second, the driving question and associated contextualization activities are developed based on relevance and interest to urban middle-school students and worthwhile content coverage needed to address the question. The third step is to develop the sequence and structure of the inquiry activities and benchmark lessons to align with our seven design principles, with particular attention paid to the integration of appropriate technology to support learning.

An initial, usually abbreviated pilot test of the project is conducted in one or two classrooms in Detroit. These pilot tests are characterized by intensive observation and professional development, as the classroom teachers, university researchers, and students negotiate the successes and difficulties of the newly formulated project. We gather and analyze the data collected from this pilot to determine where teachers and students had difficulty and what parts of the curriculum may be missing. In addition to observational data, we also collect student artifacts and conduct student and teacher interviews. Following the pilot there is a second phase of intensive curriculum development and revision that uses this data and analysis to improve the project. Such revisions include reworking or replacing lessons or investigations, adding teacher support within the materials, developing and working in the transition and reflection/meaning-making activities, and evaluating content and process objectives for their linear development throughout the unit.

From this point the project transitions into an iterative cycle of enactment, analysis, and revision. Figure 1 illustrates this development and revision cycle. During enactment, teachers receive professional development in the form of individual in-class support and larger group workshop sessions. Additionally, in-depth data collection is conducted during each enactment. This includes videotaped observations of classroom enactment, pre- and posttests administered to measure content and process skill gains, individual student interviews for content and process skill understandings as well as attitudes towards the project and science in general, a survey to gauge student attitudes about science, collection of student artifacts, and teacher exit interviews. Later in the methods section of this paper we discuss the data analysis and resulting revisions in greater detail.

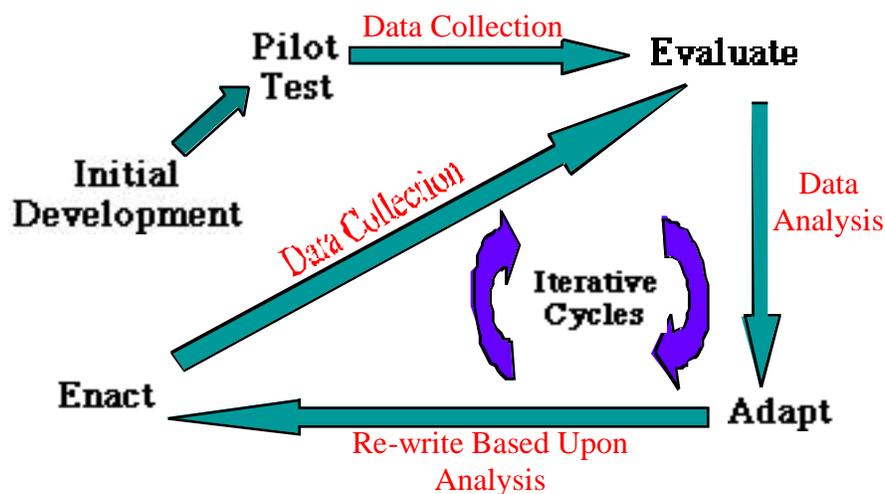


Figure 1: Development and Revision Cycle (Singer, 2000)

The Curriculum Materials

During the four academic school years from 1996 – 2000 the collaborative curriculum design effort of Detroit Public Schools and the Center for Learning Technologies in Urban Schools has developed and piloted five extended inquiry projects. These projects

have focused on a wide range of concepts that include: a) physical science (force and motion), b) chemistry (particulate nature of matter, chemical changes, and physical changes), c) geology (hydrology, erosion, and deposition), and d) biology (cells, microorganisms, immunity, and respiration). These units also represent a range of stages in the development cycle. These curriculum projects were created by applying the seven design principles through the design process described above.

Table 1: Curriculum Projects Enacted in Detroit, 1998-2000

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	8	627
		Fall, 1999	9	900
What is the Quality of Water in My River? (water quality)	7	Spring, 1999	8	615
		Spring, 2000	12	1200
Can Good Friends Make Me Sick? (communicable diseases and the immune system)	8	Spring, 2000	1 (pilot)	30

Curriculum materials for two separate 8 to 10-week units were the subjects of this study. The topics covered in these units were: 1) force and motion for 8th grade and 2) mechanical advantage for 6th grade.

In the force and motion unit students investigate the driving question, "Why do I need to wear a helmet when I ride my bike?". This question is designed to lead students through an inquiry into the physics of collisions, including the concepts of Newton's first law of motion, velocity, acceleration, and force. An unprotected egg riding a cart, representing a student riding a bicycle, is used to illustrate a collision. The egg and cart demonstration is also the focus of the final artifact, where students create and investigate a helmet for the egg to demonstrate their understanding of collisions. This unit includes several investigations that focus on independent, dependent, and control variables as well as the concepts listed above. Use of motion sensors to create computer-generated graphs of motion is included to develop understanding of velocity and acceleration, as well as reading and interpretation of motion graphs. Students also use motion sensors in their own investigation of their egg helmets. The final presentation is designed to allow students to develop and apply their knowledge of collisions and investigations as they present the test of their helmet to protect an egg during a collision.

The mechanical advantage project 'How Do Machines Help Me Build Big Things?' is designed for sixth grade students. During this six-week project students learn about the concepts of balanced and unbalanced forces, motion, and the mechanical advantage provided by simple machines. The project is set in the context of developing a new machine to use to construct new buildings. Students go on a walking tour of their city and view an active construction site. Throughout the project students are asked to relate the concepts they are learning back to their ideas for their new machine design. Students explore the concepts of balanced and unbalanced forces and their relation to motion using force probes. Then students work in groups to investigate the principle of mechanical advantage in the case of three different simple machines. Each group member designs and conducts an extended investigation into one of the simple machines, and brings their expertise back to the group for the development of their new machine design. The project culminates with the students creating a drawing or a working model of their building machine which uses at least three simple machines, and each group develops a presentation of their machine and their understanding of the science concepts behind how their new machine will function.

Data Sources

The force and motion curriculum materials have been enacted and revised twice since pilot testing, fall 1999 and fall 2000. The focus for this study was the curriculum revisions based on large-scale enactment of these piloted materials. The mechanical advantage curriculum materials were pilot tested this year, fall 2000. These units were enacted in a total of 35 urban middle school classrooms by 10 teachers involving more than a 1000 students.

All teachers were visited twice weekly and observational notes recorded. Two focus classrooms were selected for each unit and were videotaped daily during the majority of the project enactment, resulting in approximately 100 hours of videotape. Student achievement was measured with written pre and post-tests administered to all students, as well as structured student interviews given to four target students per focus classroom, 36 students total, at the end of each unit enactment. All teachers were interviewed at the close of each project, as well as university personal that supported teachers during the enactment of the unit. Interviews were audio taped and included questions about each section of the curriculum unit, how well the lessons supported student learning, areas of challenge or success for teacher or students, and recommendations for improvements.

Analysis

A detailed summary of each videotape was prepared that contained descriptions of teacher and student behavior and conversation. These descriptions were then divided into episodes and coded according to the type and substance of instruction. Written summaries of each interview were prepared that contained descriptions of teachers or support persons' ideas about weaknesses and strengths of the curriculum materials.

Student pre-post tests were statistically analyzed for significant improvements on each of the main concepts, both content and process, identified for each project . These same

concept themes were used to create scoring rubrics used to analyze student interviews. In addition, any students ideas, either scientifically correct or not, that appeared relevant to understanding students' conceptual development were noted.

Each of these data sources were analyzed independently, and then brought together to form a whole picture of the project's enactment. Written pre-post test results, student interviews and classroom videotape of student behaviors and conversation gave us information about student learning both during and as a result of the project. We looked specifically for indications of developing student understanding of the concepts identified as a focus in each unit. The extent to which the materials facilitated teachers' enactment of inquiry practices recommended in the unit, both through use and adaptation of the materials, was evidence in both classroom videotape and interviews of teacher and support personnel.

We aggregated our data sources and identified areas that needed improvement, by creating summary charts to synthesize and describe our concerns. We then considered ways to revise the materials such that we were still aligned with our design principles while at the same time improving student learning, usability and adaptability.

Findings

We have begun to define a method with which to examine and revise our curriculum materials. In this section we describe two themes that emerged from cycles of justified revision decisions across curriculum units. First, we found that each of the data sources were uniquely valuable yet consistent with other sources. Second, we found that multiple years of enactment are also uniquely valuable. We describe our emerging method for using classroom research to revise curriculum materials according to each of these themes below.

Value of multiple sources

We found that it was important to first define the focus with which we would examine each source. In our work, we focused our analysis on four main science concept clusters per unit. For example in the force and motion unit, four content and two processes concepts were identified in the materials as the focus for instruction. These included concepts of motion, velocity, acceleration, force, identification of variables, and working with line graphs. We began by looking at the concept of force. We later repeated our examination around the concept of acceleration then each of the other main concepts. This was repeated for each curriculum unit. It should be noted, however, that although we used an individual concept as a focus for revision we did not neglect to consider how this concept interrelates with other concepts and processes in the unit.

The order in which we examined each source of evidence facilitated the analysis of the curriculum as a whole. Initial examination of student data, such as posttest gains and interviews, informed and defined the analysis of classroom data and likewise for related teacher data. We also found that there was consistency to identifying concerns across data

sources, yet each told the story in a different way. For example, in the force and motion unit student pre-post test gains indicated that students were having difficulty understanding acceleration. Post-test data however, gave us a very incomplete understanding of curriculum issues at play that resulted in this outcome. We did not know why students did not appear to understand acceleration or what their thoughts were about this topic. Therefore we needed to talk to students to see what they were thinking, not just what they did not understand. When listening to student descriptions of the motion of a sled down a hill in student interviews, we found that students were using the terms velocity and acceleration as synonyms. This led us to look at the enactment of lessons for both velocity and acceleration. Here we found that students were not supported well by the materials in the process of integrating their understanding of velocity with ideas about force and motion before continuing on to explore acceleration. We also saw additional instances during enactment of student not making a distinction between the two ideas. In addition, teachers reported difficulty with the lesson intended to transition students from velocity to acceleration. This lesson utilized a plumb bob and a variety of constant and changing motions to indicate when speed or direction was changed. The teachers did not understand how this activity demonstrated changing velocity. We found that this sequence of data analysis - first test data, student interviews, enactment data and finally teacher and support person interviews - facilitated our revision process for activities and support materials related to the concept of velocity in this unit.

This example also illustrates that while we were guided by a concept and used each source in order, we also found each source to be unique and valuable in the information supplied. Student data guided us toward the ideas that students were having trouble understanding. Listening to students' ideas, both in structured interviews and during classroom enactment, helped us to understand how student were thinking about the concepts. The enactment data also shed light on why this might be the case. We could observe how students were supported by the curriculum materials and how the teacher used the materials to support the students. Teachers also were able to tell us about challenges related to the lessons included in the materials. Our example also highlights the way that each source told this story in a different manner. When we integrated the sources, however, we saw a consistent story about the blending of velocity and acceleration ideas by the students, the materials, and the teachers.

The use of multiple data sources examined in the order listed above to define concerns was also seen in mechanical advantage unit after its first full pilot. Initially there were three investigations that student groups completed in order to develop the concept of mechanical advantage. Although data from student posttest gains showed some improvement in this area, interview data indicated that students were not developing a complete understanding of this concept. There were still strongly held misconceptions about force and machines that prevented students from being able to apply the idea of mechanical advantage to more sophisticated contexts, such as the operation of complex machines. Classroom observations showed that students frequently did not have a clear understanding of the steps in the investigations. Students struggled with skills such as measurement and graphing, and thus their focus was on the mechanics of the activity instead of the science behind it. Teachers also expressed concern that students were

having too much difficulty with this set of activities. Although the process was repeated three times, they felt students were not developing investigation skills until the third iteration and were not making connections between the investigations.

Before we make a final decision on a revision, we revisit our theory-based design principles. For example, we feel that collaboration and discourse are important aspects of learning science. We analyzed the materials in the force and motion project for instances where we supported student discussions about velocity separate from acceleration, and found that students needed more opportunities and more supports in this area. We included a more structured opportunity for these conversations through the development of repeated cycles of concept mapping. Usability of the materials was also a concern. Teachers' difficulty understanding the plumb bob activity led us to think about our principle of supporting and scaffolding teachers. Revisions included a better description of the underlying science, additional take home activities for students, as well as specific information about students' difficulty understanding acceleration in terms of changing velocity. We also highlighted this portion of the unit for more intense professional development during our summer institute.

This process of reviewing our design principles before revising the materials can also be seen in the example from the mechanical advantage unit. One of our principles is the use of scaffolds and supports to develop students' understandings. By reviewing and aggregating from data sources, we determined that it was necessary to revise the sequence of investigation activities to more fully develop the concept of mechanical advantage in simple machines. Each of these data sources pointed to the need for more student scaffolding throughout this set of activities, in order to provide more opportunities for students to develop a conceptual understanding of what they were doing. Instead of students repeating the same sequence of steps in each investigation with the hopes that they develop both investigation skills and concepts, the activities are now sequenced to provide more supports for students' development of concepts and skills. The focus of the first investigation is now on collecting and representing data, with the teacher modeling ways to think about data. In the second iteration students collect, represent, and think about their own data. In this phase the students are supported in making sense of the data and drawing conclusions from investigations. The third investigation involves the students in the whole investigation process, including supporting the development of concepts from the results of the three investigations. Through this more scaffolded and supported sequence, students will have greater opportunities to develop both conceptual ideas and investigation skills.

Value of multiple enactments

We completed this process of examining multiple sources in light of design principles for different units over different stages of enactment. While we maintained a relatively consistent pattern of analysis across the project, we found that different types of revisions arose which depended upon the number of cycles of analysis, adaptation, and enactment that the unit had completed. Data collected from initial enactments, such as the recent

completion of the pilot of the mechanical advantage unit, resulted in larger changes in the activities and their sequence. These changes also tended to be focused on student understanding issues rather than teachers' ability to translate the materials into inquiry in their classrooms.

For example, data from the pilot test of the mechanical advantage project showed that students did not clearly understand the role of force to explain how machines worked. Students successfully engaged in a set of investigations around balanced and unbalanced forces at the beginning of the unit. However, they subsequently did not use this information to help explain how machines functioned and why it was important to use machines. This is an important idea to understanding the purpose of machines and the concept of mechanical advantage. Thus, in revisions of the mechanical advantage project, the connections between concepts of force, machines, and mechanical advantage are made more explicit, and both student and teacher supports have been added to emphasize the links between these ideas.

On the other hand, the force and motion unit has been involved in this iterative revision process three times over the course of the past three years. We are now making revisions that address the finer points of student understanding and are beginning to consider the usability of the materials more strongly. For example, after the fall 1999 enactment we were concerned that students did not recognize when objects were moving in relationship to the earth. Students' observations of the egg and cart demonstration would include statements such as the egg and the cart were not moving, only the wheels of the cart were moving because they were turning. Revisions were made to help student understand reference points and that moving is changing distance over time from a reference point. In the following enactment we found an improvement in students' ability to recognize objects in motion relative to the earth. Since that revision has been made, however, we have now identified that students have difficulty recognizing different rates of motion, such as increasing speed while the cart rolled down the ramp. This issue will be addressed in the next iteration of revisions and enactment.

The most recent enactment of the force and motion unit also made evident that teachers needed additional support to use and adapt the materials as one-on-one classroom support was decreased. For example, in earlier enactments where there was intense professional development and classroom support, teachers were able to use the materials to guide students through a prediction-observation-explanation (POE) cycle using motion sensors to explore motion of different speeds and direction. However, later enactments involved scale-up issues with greater numbers of teachers involved and less available classroom supports. With more reliance on the materials by more teachers, the POE cycle was often abbreviated. Teachers did not understand the purpose of the pedagogical POE method of presenting information, and thus frequently enacted it ineffectively or presented the content without using the pedagogical support. The materials were not as usable as we had hoped. Additionally we found the need for more information for teachers to understand how POE with the motion sensors supports student learning.

Conclusions

In this paper we have presented our method of revising curriculum materials based on multiple sources of classroom data and concordant with theories of learning as embodied by our development principles. First, we found that each of the sources of data contributed uniquely to our understanding of needed improvements and were consistent with other sources. The order in which we incorporate each source - first test data, student interviews, enactment data and finally teacher and support person interviews - facilitated our understanding of the needed curriculum improvement. It was also essential to incorporate theoretical constructs, as instantiated in our design principles, with our classroom data before recommending a revision in the curriculum materials. Second, multiple years of enactment also contributed, each uniquely, to the revision process. Initial enactments highlighted general issues, such as sequence and student learning issues. Subsequent years illustrated more specific and sequential student learning issues. Additional years of enactment also made evident usability and adaptability issues. As more teachers with less one-on-one support enact each project, challenges for teachers using the materials become more evident. As teachers enact a unit over the course of multiple years, the ability of the materials to be adapted to each teacher's particular situation and context also comes to light.

We have found that through each phase of this iterative process of enactment, analysis, and revision, the curriculum projects become more complete, as well as more usable by a broader range of teachers. The activities build on each other, the sequence becomes more appropriate for middle-school students, and the activities make the concepts addressed in each project more salient. Each progressive iteration involves scale-up issues as well, as increased numbers of teachers, students, and schools participate in the projects. The ability for us to observe the curriculum projects in a variety of classroom settings enables us to fine-tune the curriculum materials to be user-friendly for teachers of all abilities across the district, as well as provide us a realistic view of the potential of our projects to help students learn science content and process skills.

Research on reform-based curriculum enacted in the complexity of classrooms is itself complex. We begin to define a rigorous method for drawing meaning from a complex situation and data (Miles & Huberman, 1984). In order to gain meaningful information on which to base revisions of curriculum materials, a variety of sources of data need to be explored in a systematic order and integrated during analysis. Each source gives valuable insight but only in light of the other sources and our underlying theoretical principles. Based on initial field tests, we have strong evidence that students learn important science content by participating in our inquiry projects. Our observations of classrooms also show that although challenges exist, teachers can enact these units. We are encouraged that a method of classroom research can be defined that supports real curriculum improvement in terms of its support for student learning, and its usability and adaptability for teachers. Our description of our process of revision of curriculum materials base on data and theory is the beginning of the development of a justifiable protocol of researching and improving curriculum materials. It is important to continue to refine our curriculum revision method as we create curriculum materials to support reforms in

science education. This work holds promise for reforming education in our urban public schools and informing other curriculum efforts.

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Appendix A

Curriculum Design Principles

Design Principle	Description	Instructional Component
Context	Meaningful, defined problem space that provides intellectual challenge for the learner	<ul style="list-style-type: none">• Driving Questions• Sub-Questions• Anchoring Events
Standards based	Publication by larger community experts that defines the language and methods of the larger community	<ul style="list-style-type: none">• AAAS –Benchmarks• NRC–National Standards• Benchmark lessons
Inquiry	The accepted method of the scientific community for solving problems. It is a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena (NRC, 1996 , p. 214)	<ul style="list-style-type: none">• Asking Questions• Data collection,• Organization and analysis• Sharing and communicating data
Collaboration	Interaction students, teachers, and community members to share information and negotiate meaning	<ul style="list-style-type: none">• Small group design meetings• Think, pair, share learning strategy• Group presentations
Learning Tools	Tools that support students in intellectually challenging tasks	<ul style="list-style-type: none">• Data Collection• Communication• Modeling
Artifacts	Representations of ideas or concepts that can be shared, critiqued, and revised to enhance learning.	<ul style="list-style-type: none">• Concept maps• Scientific models• Lab reports
Scaffolds	A series of methods which fade over time to control learning activities that are beyond the novices' capabilities so that they can focus on and master those features of the task that they can grasp quickly (Schunk, 1996)	<ul style="list-style-type: none">• Learner centered design• Teaching strategies• POE: Predict, observe, explain• Driving Question Board

From Singer, Marx, Krajcik & Chambers, in press.