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AUTHOR	Krajcik, Joseph; Marx, Ron; Blumenfeld, Phyllis; Soloway, Elliot; Fishman, Barry
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ABSTRACT

Inquiry is an essential component of science. Furthermore, what students learn and how they engage in inquiry supported by technology is important to understand in order to promote science education reform. This paper presents an overview of work in curriculum and technology development and professional development. Collaboration with the Detroit Urban Systemic Program is described, and focus is placed on a study of the performance of urban students on pre- and post-tests in four different inquiry-based and technology-rich curriculum units. (Contains 13 references.) (WRM)

Inquiry based science supported by technology: Achievement among urban middle school students

Joseph Krajcik, Ron Marx, Phyllis Blumenfeld, Elliot Soloway, Barry Fishman

University of Michigan, School of Education, Ann Arbor, MI

Introduction

Inquiry is an essential component of science. NRC (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). 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 discuss the implications of our findings.

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., 1993, Krajcik, Czerniak, & Berger, 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.

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, 1999). Furthermore, the curriculum materials themselves are intended to be "educative" for teachers (Ball & 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 (Jackson, Krajcik, & Soloway, 1999; Krajcik, Blumenfeld, Marx, & Soloway, in press).
- **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' Workshop1 is a suite of computational tools we developed to enable sustained inquiry (Krajcik, Blumenfeld, Marx, & Soloway, 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). Some software, like ModelBuilder, is designed for use at single

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

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, & Soloway 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), 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).

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 eight 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^{th} 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^{th} 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). 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). We also have described building level challenges such as resource allocation and scheduling Blumenfeld et al., in press).

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.

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, 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.

Methods

All students in LeTUS curriculum projects are assessed by tests designed to match DPS curriculum standards. Pre and post- tests, motivation surveys and student artifacts and interviews on a small subset of students were collected in these classrooms. However, in this paper we report only the results from pre- and posttest measures of learning. Tests were created to measure both content and process understanding across several cognitive levels – low, medium and high. Correct responses were tallied for the multiply choice. Rubrics were created for open-ended items. Science educators prepared to score the various items scored the open-ended items. Inter-rater reliability was established between scorers. The test construction process is show in Appendix 1. Example test questions for the various curriculum units are presented in appendix 2.

The LeTUS curriculum projects have impacted over 2,000 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

All students took the pre- and posttests. However, due to absences and mobility among students from the administration of the pretests and the posttests, there was considerable attrition. Table 2 shows the numbers of teachers, classrooms and students who provided data for the analyses reported here. We are not reporting data for Can Good Friends Mark Me Sick because data are not yet available.

Findings

Table 2 presents means, standard deviations and effect size of pre and posttests. Total scores as well as scores on the content and process components are reported.

Student performance on posttests shows improvement across implementation of all projects. Table 2 shows learning outcomes by students for the past two years in the various curriculum projects for which we have analyzed data to date. The effect size column indicates the average gain on the posttest measured in pretest standard deviation units. Effect sizes for total score and scores on the content are all statistically significant. Effect sizes for process scores are significant with exception of the bicycle helmet unit in fall 98 and water quality in spring, 99.

In the bicycle helmet unit in fall, 98, overall and content scores, but not process scores, increased significantly. The low number of items and small sample size may have prevented the gain in process scores from reaching a significant level.

It is important to note that the mean effect size is .87 for the total scores across all units. Thus, across all of these units, the average total score was around the 80^{th} percentile of the distribution of scores on the pretest. Given the early stages of development of the units, the tests, and the teachers' capacity for enacting inquiry with technology, we believe that the data indicate that students are learning important science content related to national and local science education standards. Most of this success was related to science content (the average effect size on content items was .84). We had less success with the process items (average effect size of .42). As we revise curricula, we will focus on improving students' opportunities to learn science processes and we will address pedagogical issues concerning science process in our teacher professional development activities. We also will need to address measurement issues regarding these important science education standards.

It is important to note that there are large effects due to teacher differences. Figure 1 compares the average gain score to the lowest and highest gain scores for the three curriculum units enacted in fall, 1999. For the Air Quality and Force and Motion units, there was considerable variability in average gains for students across the teachers enacting these units. There is less variability in the gain scores for the Big Things unit, because there were only two teachers enacting it.

Figure 2 shows the gain for each of the teachers who enacted the air quality curriculum in fall, 1999 (Figure 2 is an expansion of the data represented in the second set of bars in Figure 1). It is clear that these teachers show a substantial range of gains. The two lowest scores on this table, which in a sense are outliers, are from two teachers that have more general pedagogical problems then enacting inquiry based curriculum

Table 2: Curriculum Implementation—Student Outcomes (significance level, $^{**}p<0.01$)

Curriculum	Year	Number Sts/teachers	Question Type (n)	Pretest Mean (SD)	Posttest Mean (SD)	Effect Size
Why Do I Need to Wear a Bike Helmet? (8th grade, force and motion)	Fall, 1998	82/3	Total (36)	15.0 (4.99)	20.3 (8.0)	1.12**
			Content (29)	11.1 (3.93)	16.4 (6.79)	0.70 **
			Process (7)	3.95 (1.62)	4.09 (1.79)	0.09
	Fall, 1999	485/8	Total (20)	6.0 (1.96)	7.18 (2.89)	0.60**
			Content (14)	4.18 (1.60)	5.10 (2.28)	0.58**
			Process (6)	1.81 (1.12)	2.08 (1.17)	0.23**
What is the Quality of Air in My Community? (7th grade, chemistry principles)	Fall, 1998	438/9	Total (20)	9.36 (4.79)	11.72 (5.52)	0.49**
			Content (13)	5.55 (2.52)	6.51(2.76)	0.38**
			Process (7)	3.77 (3.17)	5.21 (3.56)	0.45**
	Fall, 1999	500/9	Total (20)	6.49 (3.04)	10.2 (4.72)	1.23**
			Content (14)	3.67 (1.86)	6.19 (3.07)	1.35**
			Process (6)	2.81 (1.93)	4.04 (2.25)	0.64**
What is the Quality of Water in My River? (7th grade)	Spring, 1999	290/10	Total (24)	8.25 (4.06)	9.96 (5.10)	0.42**
			Content (15)	4.74 (1.96)	6.03 (2.49)	0.66**
			Process (9)	3.51 (3.0)	3.95 (3.68)	0.15
How can I build big Things (6th grade, mechanical advantage)	Fall, 1999	179/2	Total (20)	9.78 (3.67)	14.8 (5.19)	1.36**
			Content (14)	7.03 (2.56)	10.51(3.31)	1.36**
			Process (6)	2.74 (1.55)	4.26 (2.23)	0.98**

Figure 1: Teacher Effects

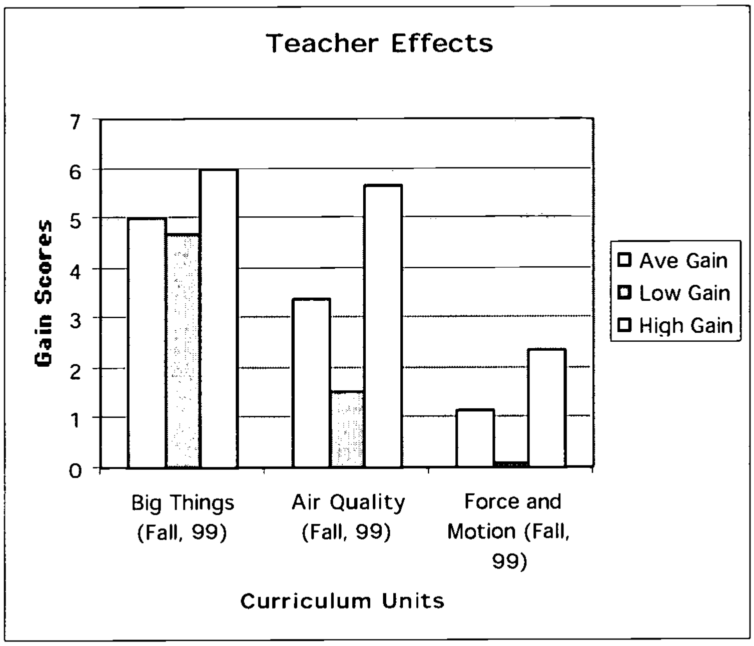
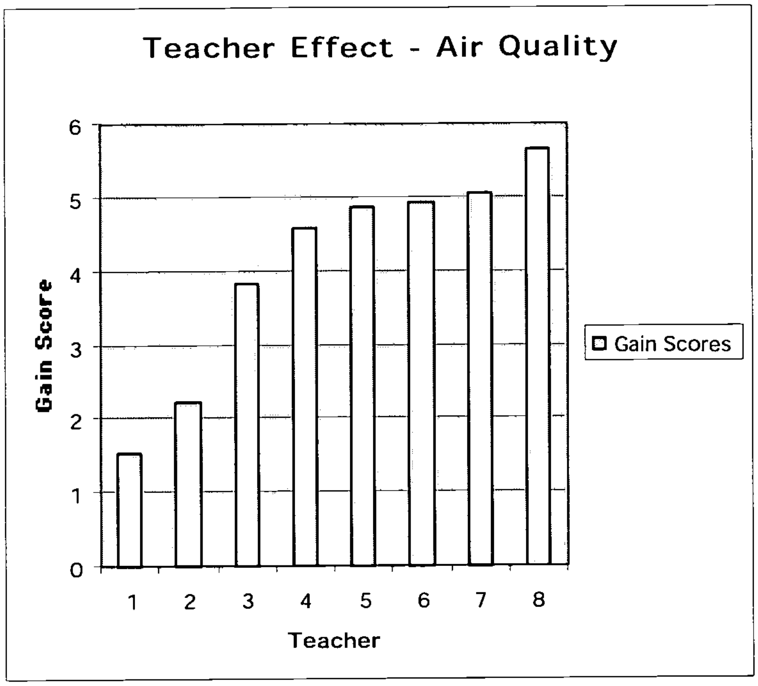


Figure 2: Teacher Effects – Water Quality Spring 99



Discussion and Implications

The data reported here show that these urban middle school students learned from an inquiry-based science curriculum supported by technology. Achievement gains were found in all four curricula across both years for overall score and content based scores. Scientific process scores improved in most of the curricula as well. The results, however, are not proof of success in the traditional sense. Each year there have been changes in the curriculum, the tests, addition of new teachers not experienced with the curriculum, and high turnover in student populations. Therefore, the data were not collected under controlled conditions to demonstrate consistent improvement over time or to compare effectiveness of our approach with those of others. Instead, the results should be seen as a sign that students can benefit from this approach even when it is still evolving in the setting.

In fact the results show that there is considerable variability by teacher. Like most research that includes more than one teacher, these findings show that teachers are among the many factors that can influence students' learning. We have shown elsewhere

(Blumenfeld et. al, 1993) that it takes about three years for teachers to change their teaching from a more transmission to a more transformation approach. Some of the teachers who participated in the work described here have been involved in this program for that length of time. Yet, even the simple measure of the number of years a teacher has been engaged in reform efforts is not the full answer. Some teachers who were in their second year of enacting these units had students who performed at levels lower than new teachers. Obviously a range of issues interact to produce these effects. The schools serve communities that differ in many ways, including the relative economic security of the families and other indicators of social capital. There are differences in the resources available to classroom teachers in all of these schools, and administrative support varies as well. In addition to these and other factors associated with the schools, we have found that it takes several iterations of curriculum development in order to fine tune the units so that they can better engage students in science inquiry and capitalize on the possibilities afforded by new learning technologies (Singer et al., in press). Moreover, we believe that our teacher professional development activities successfully engage teachers in a range of critical learning opportunities. Yet we are convinced that we can do a better job and are in the process of revising and improving our efforts in this arena (Fishman et al., 2000).

Our aim is to continue to work with the district to improve the curriculum, make the technology more readily available and enhance professional capability so that all students can achieve these results.

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Appendix 1: Constructing the tests for 1999-2000 curricula

Guidelines for test construction

- The tests should have good structure validity with the unit, meaning cover all the learning sets, major concepts and skills learned using our curricula.
- Equal no. of items in all tests (air big things, physics and water) – total=20
- Equal ratio for content vs. process items – 14 content, 6 process.
- Equal no. of open ended questions – 2 items, each equals 3 points (over all points is 24)
- The same proportion of low/medium/high order skills in all tests – 8 low; 10 medium; 2 high.
- Administration – one class period
- One test version in order to decrease reliability and scoring problems and mistakes.
- For each test - process skills focus on ones that were experienced in class and are also in the context of the curriculum. (No pendulum questions in the air test)
- Using as many relevant standardized test items (TIMMS or NAEP) as possible
- Scoring each open ended questions for 3 sub skills/content
- Editing the final version for language, representations and typos
- Expectations for answers should be clear (content validity?). Initial rubric has to be constructed with the open items.

Appendix 2: Sample Questions

<u>**AIR**</u>

<u>Low</u>

4. Which substance occurs in the largest amount in "clean" air?

   A. nitrogen
   B. oxygen
   C. sulfur dioxide
   D. carbon dioxide

medium

18. A class is investigating how the strength of acid rain affects plant growth. Four small gardens are given different strengths of acid rain. After two months the height of the plants is measured. The data are shown in the chart. Using this chart what can you conclude?

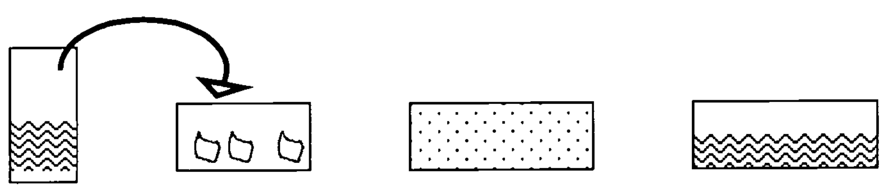
Garden	Strength of Acid Rain	Average plant height
1	No acid	40 centimeters
2	Weak	35 centimeters
3	Medium	20 centimeters
4	Strong	10 centimeters

A. Increasing the strength of acid rain decreases the height of the plants.
B. Increasing the strength of acid rain increases the height of the plants.
C. Decreasing the strength of acid rain decreases the height of the plants.
D. Decreasing the height of the plants increases the strength of acid rain.

High

19. A class conducted an experiment in which they combined the following.

A clear liquid was poured in to a dish that contained 3 small gray rocks.
The students noticed that the rocks began to bubble, fizz and become hot. After about 20 seconds the small gray rocks were gone. The dish was hot and contained a liquid



Clear liquid gray rocks lots of bubbles fizzing, and heat hot and liquid

Write a short paragraph that explains what happened. Be sure to include the following:

- What kind of change occurred
- Evidence supporting how you know this type of change occurred
- Description of what happened to the molecules in the gray rocks

PHYSICS

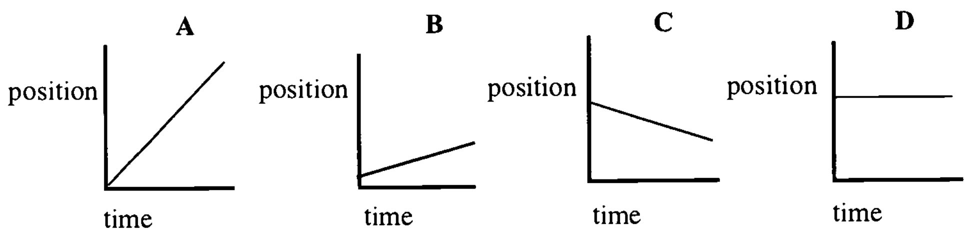
Low

5. In order to have a change in velocity of a car, there must be a change in

a. its speed.
b. its direction..
c. either its speed or direction
d. both its speed and direction

Medium

15. Which of the following position-time graphs shows a person moving closer?



a. graph A
b. graph B
c. graph C
d. graph D

High

14. It is less dangerous to jump from a 5 foot high wall onto very loose sand than onto concrete pavement. You may be injured by the force involved in landing. Use ideas like speed and acceleration.

a) Explain why there is a force when landing.
b) Explain how acceleration affects the force in landing.

Explain why the force in landing on loose sand would cause less injury to you than the force in landing on concrete pavement.

Big Things

Low

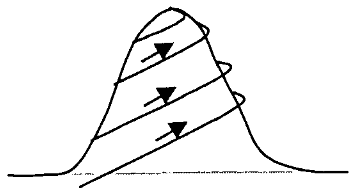
- Balanced forces result in

A. no change in motion.
B. motion to the right.
C. a strong push.
D. motion upward.

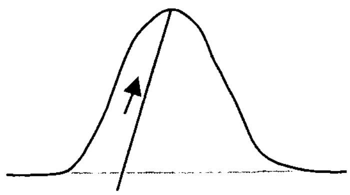
Medium

11. There are four paths up to the top of a mountain. Which one requires the MOST force to climb the mountain?

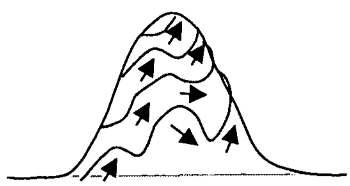
A.



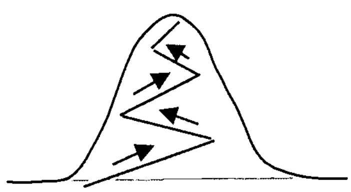
B.



C.



D.



High

12. Explain why it is easier to use a screwdriver to open a can of paint instead of using just your fingers. Use the terms machine, force, and distance in your response.

Water

Low

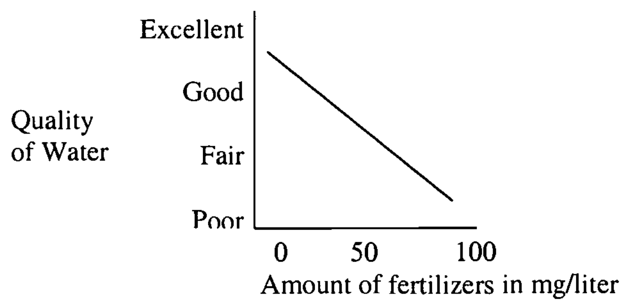
When it rains, water falls on the ground. Some of this water soaks into the ground and some evaporates back into the air. What else can happen to water after it rains?

a) Run-off
b) Watershed
c) Deposition

d) Erosion

Medium

- A science class is studying water quality. They found the following graph in their local newspaper.



Using the data in the graph you can conclude that as the amount of fertilizers

a) increases the quality of water increases
b) increases the quality of water decreases
c) decreases the quality of water decreases
d) increases the quality of water stays the same

High

20. A power plant has an outlet pipe which releases warm clean water into a cool water river in Michigan. A class studied how the temperature of the water affects the number of different kinds of animals in the river during the summer months.

The class hypothesis was: the higher the temperature of the water the fewer kinds of different animals in the river.

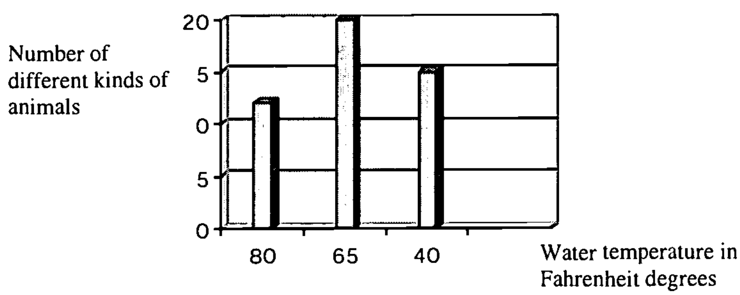
The class decided to use three similar spots along the river. All the spots had the same conditions. But because they were a different distance from the outlet pipe, the spots had different water temperatures.

The class collected the animals at the same time during the day and used the same method to collect the animals from all 3 spots.

The table shows the temperature of the water and the number of animals collected.

Water temperature in °F	The number of different kinds of animals
80	12
65	20
40	15

The number of kinds of animals in different temperatures



Using all the information you have,
a) describes the results
b) write your conclusion
c) does the conclusion support the class hypothesis?

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