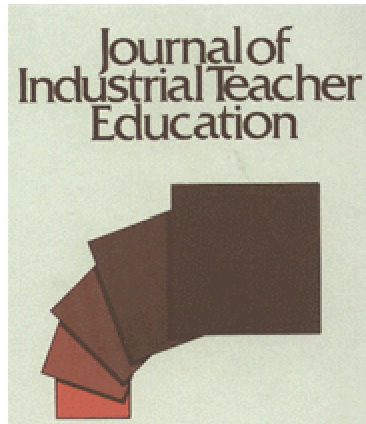

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Introducing Technology as a School Subject: A Collaborative Design Challenge for Educators

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Technology has not yet achieved its full potential as a school subject in the U.S. This paper proposes that technology education should focus on everyday artifacts and design problems, and thereby remove some of the barriers preventing its introduction into the schools. Curriculum materials and teacher support will be essential to this effort. However, traditional modes of curriculum development and professional development will not be effective, because they fail even to engage teachers, let alone exploit their expertise. A new paradigm is needed, which sees both tasks as collaborative design challenges that must involve teachers as full participants. The paper concludes with an extended account of the City Technology project, based at the City College of New York, which put many of these ideas into practice.

What is Technology Education?

The word "technology" has evolved through several different meanings during the recent history of education. In 1985, the American Industrial Arts Association changed its name to the International Technology Education Association. This change reflected dissatisfaction with traditional "shop" courses, designed to prepare students for skilled trades and technical vocations. Instead, it was felt, *all* students needed to gain some familiarity with technology, to prepare them for life in a rapidly advancing, technologically sophisticated society (Cheek, 1992, p. 54). Although the objective is worthy, the transition from Industrial Arts to Technology Education is still a work in progress. Much of the Technology Education community still has its roots in Industrial Arts, and Technology has yet to become firmly established as a school subject in the United States.

Meanwhile, the word technology has been appropriated, in both the popular imagination and in most educational circles, by those who identify it solely with computers. Worse yet, there are some who define the term even more narrowly. For example, the Chairman of the Federal Reserve Board recently identified technology education with learning to navigate the Internet (Crutsinger, 2000). Of course, a computer *is* an example of technology, but no more or less so than the box it came in, the packing material and tape used to protect it, the "Fragile" symbol printed on the box, the desk or table it sits on, or the pencil and paper it replaces!

For beginning the study of technology, computers are not the best subject matter, because they are difficult to understand beyond the user level. Other examples of technology, often introduced at the middle-school level, are also unnecessarily complex. These include bridges and robots. Many other technologies are much more accessible - and cheaper - and still illustrate the fundamental concepts that are the basis of the more complicated large-scale or high-tech artifacts. For example, a shopping bag is a *structure*, which has the same basic purpose as a bridge: to support a load. By testing shopping bags and analyzing how they fail, you can learn a great deal about how structures work. A robot is an example of a *mechanism*, whose basic elements are levers, which are also the fundamental components of a pair of scissors, a nail clipper or an eyelash curler. Computers are designed to encode, process and decode information. The same processes of encoding and decoding occur with much simpler codes, such as the key to a map, sign language, a zip code or a bar code. To learn about technology, it is much easier to start with these much simpler, already familiar examples, such as shopping bags, eyelash curlers and map symbols.

Using a broader definition of technology, it is customary to include all of the artifacts humans have invented to improve their lives. However, even computer technology includes more than artifacts, or hardware. There is also the software aspect of technology: the plans, practices and arrangements for organizing and utilizing the hardware. These terms, "hardware" and "software," apply just as well to other areas of technology. Just as a computer program is a plan for organizing computer hardware, a room arrangement is a scheme for making the best use of furniture, another kind of hardware. Therefore, we include as technology not only artifacts, but also designed environments. Both artifacts and environments are included by the *Standards for Technological Literacy*, which defines technology as "how humans modify the world around them to meet their needs and wants, or to solve practical problems" (International Technology Education Association [ITEA], 2000, p. 22).

What do students *do* when they study technology? An excellent starting activity is a search for examples or problems related to a particular area of technology. A search for physical examples can be called a scavenger hunt, while a collection made from imagination or experience is a brainstorming session. For example, a study of shopping bags might start with a scavenger hunt for bags made using an assortment of materials and methods. A redesign of the classroom furniture arrangement might begin with a brainstorming session to identify problems arising from the current design of the room.

Following this initial brainstorm or scavenger hunt, there is a need for analysis. A preliminary type of analysis is often to sort the objects or examples according to important characteristics. For example, shopping bags may be sorted according to the way their handles are made and/or attached. In looking at the problems with a classroom furniture arrangement, some categories might be (a) access to supplies, (b) traffic flow in the room, (c) providing space for whole-class meetings, and (d) promoting group work. Often, it is useful to collect and analyze quantitative data. Students may test shopping bags by seeing how much weight they can hold. Or, in addressing the problem of classroom interruptions, they might collect data to determine the frequency and source of the interruptions. This kind of data can provide a sound basis for developing solutions.

Identifying a problem with an existing technology serves as a trigger to begin a process of design, which many identify as the key to the study of technology. The *Standards for Technological Literacy* characterizes design as "the core problem-solving process. It is as fundamental to technology as inquiry is to science and reading is to language arts" (ITEA, 2000, p. 91). Often, a design project does not proceed from "scratch," but rather starts with an existing design. Examples of partial design projects include redesign, repair, and re-use. Any sort of design project, however, has the following characteristics:

1. There is a real problem-or, more likely, set of problems-to be solved.
2. There are many possible solutions.
3. The first solution is probably not the best. There should be an effort to evaluate each solution, and remedy its weaknesses through an iterative process of redesign.

We do not believe that the distinction between design and analysis (or inquiry) can be drawn very sharply. Nearly every substantial design activity includes some analysis, and vice versa. Furthermore, many of the processes of design overlap with those of inquiry. These include sorting, classifying, fair testing, data collection, data analysis, data presentation, and oral and written communication. The *National Science Education Standards* make this point in the following way: "Children in grades K-4 understand and can carry out design activities earlier than they can inquiry activities, but they cannot easily tell the difference between the two, nor is it important whether they can" (National Research Council, 1996, p. 135).

Technology education should include critical evaluation of the purposes and effects of artifacts and environments, and attempts to improve some of these technologies through design or redesign. This is a broad undertaking that can provide a context for all of the other disciplines. The overlap with science has already been outlined. Collecting data, organizing it, and pattern-finding all require mathematical thinking. Negotiating solutions and presenting them to others are exercises in written, oral, and graphic communication. The problems students solve can and should be *their own* problems, such as how to reorganize the furniture in a classroom to promote better traffic flow, or design a package for safe delivery of a fragile object. As students analyze and design solutions cooperatively, they engage in *democratic decision making*, which is a basic goal of social studies education. Technology can provide organizing themes for the entire curriculum (Benenson & Neujahr, 2001b).

Why the Benefits of Technology Education Are Largely Unrecognized

The *Benchmarks* standards document presents the current status of technology education in embarrassing terms: "In the United States, unlike in most developed countries in the world, technology as a subject has largely been ignored in the schools" (American Association for the Advancement of Science [AAAS], 1993, p. 41). This is true in spite of the fact that "young children are veteran technology users by the time they enter school…. [They] are also natural explorers and inventors, and they like to make things" (AAAS, 1993, p. 44). Given the enormous potential for technology education, why has the subject had so little impact?

The answers to this question are obvious to most educators. The curriculum is already overloaded to the breaking point. Standardized tests are promoted by politicians at the local, state, and federal levels as the "solution" to failing schools. Most teachers know better, and many teachers with seniority have voted with their feet by transferring out of the grades most affected by the tests. However, the proliferation of testing is difficult to resist, and more and more classroom time is devoted to teaching to the test. Increasingly, there are demands from parents and politicians to extend the school day or the school year, simply to "cover" the subjects already being taught, mostly in order to raise test scores. There is no room at all for something new.

To make matters worse, technology is not only considered a new subject, it is also still widely identified with computers. Few teachers have the time or technical background to become proficient in this complex area of technology. Besides, computers are expensive, break down frequently and require substantial technical support. Even for those who take a broader view of technology, and who would like to implement a program of technology education, there are few curriculum materials or professional development opportunities available.

To overcome these obstacles, proponents of technology education will need to respond with imagination and vision. They will need to identify the features of the subject that could facilitate its introduction into the schools in spite of the obvious difficulties. In our view, technology has three characteristics that offer hope for its establishment as a school subject:

1. Although technology is unfamiliar as a school subject, technology itselfis *very* familiar. Teachers as well as students are constantly surrounded by the artifacts and environments that constitute technology. Nobody has direct experience with atoms or ancient history, but everyone knowssomething about scissors, shopping bags, and schedules.

2. Technology education has less of a "top-down" character than other fields. Because the subject focuses on everyday things and problems,the technology curriculum can be flexible enough to incorporate local circumstances, experiences, and interests.
3. There are strong connections between technology and other school subjects. For example, some teachers have used the study of mechanisms, or of signs and symbols, to motivate learning disabled students to want to read and write (Benenson & Neujahr, 2002a; 2002c).

Consequently, technology can be introduced as a change of focus in other subject areas. It is not necessary to play the zero-sum game of finding something else to eliminate in order to make room for technology. To exploit these features of technology education, effective curriculum and professional development will be critical.

In the next section, we consider how curriculum development and professional development are traditionally done. Frequently, these are regarded as commodities to be "delivered" to teachers, without considering their needs as educators, or their commitment as professionals. New curriculum materials and teaching strategies are most often presented in didactic mode, with little if any attention to principles of active learning, collaborative learning, inquiry, or design. Ironically, these basic precepts of educational reform movements are most likely to be ignored, when the "students" are teachers. This approach is particularly counterproductive in the introduction of a new subject matter, such as technology, which teachers are likely to regard with some justifiable skepticism. The next section paints a picture of these traditional modes of professional development.

Traditional Models of Curriculum and Professional Development

The second author, Felice Piggott, is a New York City elementary school teacher who played a major role in the City Technology project, which is described in the last section. She has also frequently been subjected to more conventional forms of professional development. What follows is her account of how the typical professional development session feels to a teacher:

> Among my colleagues, a professional development ("PD") session is akin to jury duty. "OH NO! I have a PD session tomorrow!" is the usual response. Professional development is perceived as lost time and forced separation from one's students, classroom, and school life. A typical PD session, like jury duty, is a time when one can neither work productively, nor relax fully. Like most of jury duty, almost all PD is passive activity. It is also a time laden with apprehension and anxiety. Some questions that arise naturally are "What will my class miss while I am gone?" "How will I be able to make it up when I get back?" "What new topic will I have to teach now?"
>
> Most PD sessions are intended to show teachers the "correct" way to introduce a new curriculum. This approach may be dictated by budgetary constraints. Regardless of the motivation, it is about as effective as the attempt to enforce a "silent" lunch hour in the student cafeteria. A typical PD session proceeds in the following way. First, it is made clear to all of the teachers in attendance that we are the ones to blame. The reason we are being briefed about the new reading (or math) curriculum and its accompanying teaching strategies is that the school (or district) test scores are too low. Therefore, we are all being required to adopt the new reading (or math) curriculum, and teach it via a prescribed set of

> methods, models, and strategies. Indeed, we are expected to master these formulas by the end of the day!
>
> Then, pocket folders are distributed to all of the participants. The folders typically contain printed handouts, as well as nametags, notepads and pens. Excerpts from the printed materials are read aloud to the group. Some of this material is also projected onto a screen from an overhead projector, and/or summarized in a PowerPoint presentation. We might be asked to comment briefly on what we have seen and heard.
>
> A long lecture follows regarding the origin of the new curriculum. Sometimes this lecture is delivered by a guest speaker, but rarely if ever by anyone with particular expertise. The lecture includes testimonials and statistics proclaiming the success of this curriculum in schools somewhere else, but it not usually clear how these schools compare with ours socio-economically. Then there is an account of the new curriculum components, how they should be taught, and the expected outcomes. Sometimes there is an accompanying video, featuring a well-dressed teacher in an extremely clean and well-equipped classroom, who models delivery of the new reading (or math) curriculum to a small group of cooperative, eager, and polite students.
>
> Finally, there is a closing pep talk affirming the expertise and enthusiasm we have all gained regarding the new curriculum, simply by attending this session! We are complimented effusively for our proficiency, persistence, and professionalism. Evaluation forms are then handed out and we are told how important it is to complete them fully. Facilitators are stationed strategically at the exits to make sure everyone turns in the forms.
>
> Nearly every teacher I know would immediately recognize this particular model of PD. Of course, there are numerous variations on this theme. These include workshops or small groups led by staff developers or vendor representatives in lieu of the lecture; distribution of curriculum binders or thematically linked trade books; and timed, supervised, task-oriented collegial work sessions. Each of these is a clear improvement over the straight lecture model outlined above. However, even the variants begin with pre-ordained outcomes, and leave little or no room for the teachers to participate in the process, except as conveyor belts in the information transmission system.

None of the common forms of professional development incorporate the design frameworks now associated with best practices in classroom instruction. Most educators strive for relevant, learner-centered, project-based, democratic, and integrated curricula. The teacher's role in the classroom has evolved from that of a dictatorial and didactic expert to one of a facilitator/advisor within a community of learners. Yet the parochial and punitive notions of blame, shame, control, submission, and competition are those most commonly employed in curriculum and professional development. A recent compilation of cognitive research by the National Research Council makes the same point in the following way:

> Many approaches to teaching adults consistently violate principles for optimizing learning. Professional development programs for teachers, for example, frequently:

- *Are not learner centered*. Rather than ask teachers where they need help, they are simply expected to attend prearranged workshops.
- *Are not knowledge centered*. Teachers may simply be introduced to a new technique (like cooperative learning) without being given the opportunity to understand why, when, where, and how it might be valuable to them….
- *Are not assessment centered*. In order for teachers to change their practices, they need opportunities to try things out in their classrooms and receive feedback. Most professional development opportunities do not provide such feedback. *Moreover, they tend to focus on change in teaching practice as the goal, but they neglect to develop in teachers the capacity to judge successful transfer of the technique to the classroom or its effect on student achievement* [emphasis added]. (Donovan, Bransford, & Pellegrino, 2000, pp. 26-27)

The traditional model of professional development, described in this section, seems like a time warp from a different era. As Alfie Kohn points out, "telling teachers exactly what to do, and then holding them accountable for the results, does not reflect a commitment to excellence. It reflects a commitment to an outmoded, top-down model of control that is reminiscent of Frederick Taylor's 'scientific management' method for speeding up factory production. Is it really surprising that this approach tends to backfire" (Kohn, 1999, p. 95)?

Neither curriculum development nor professional development is generally done very well. Many curriculum materials are simply not very useful, and appear never to have been tested in real classrooms. Efforts at professional development, even if they are more engaging than those described in this section, often provide "tools and techniques that expand the teacher's repertoire, but leave her basic practice undisturbed" (Thompson & Zeuli, 1999, p. 355). Curriculum design and teacher support are difficult enough to do in areas such as math and science, which are already established as school subjects. As we have already suggested, technology education has even more barriers to overcome.

The Collaborative Design Challenge

A new paradigm is needed for both curriculum development and professional development. Treating teachers as passive instruments in the educational process is not just damaging to the morale of those most involved in the educational process. There is an opportunity cost as well. Any effort to reform education ought to make use of all of the available resources. Some of the most valuable resources-and among the least used-are experiences and reflections of teachers working in classrooms.

Classrooms are very complex social environments, and teachers are the only adults that are intimately aware of what happens in them. Curriculum developers and professional developers may have expertise in subject matter and/or pedagogy, but teachers are the experts in the social and intellectual dynamics of the classroom. As a third-grade teacher has written, "we can feel the rhythms of timing that shape the motion of the class. We are aware of the many cues we read off students' faces, words, and posture-composing our impressions of student engagement, boredom, understanding, confusion" (Ball & Lampert, 1998, p. 379). Just this sort of expert knowledge is needed for figuring out how to make technology as a subject come alive for children.

The process of design provides a framework for collaborative solutions to both curriculum development and professional development. In the case of curriculum design, this point is made explicitly by *Designs for Science Literacy* (AAAS, 2001). The design of professional development is advocated implicitly in the *National Science Education Standards* (National Research Council, 1996). Both curriculum development and professional development fit the three basic criteria for a design problem, developed in the first section and repeated here:

1. There is a complex set of problems to be solved.
2. There are many ways to solve these problems, some obviously better than others.
3. The first attempt is not likely to be the best, and an extended process of evaluation and redesign will be needed to create a useful product.

The basic problem in curriculum design is to create materials and ideas that will lead to technological literacy; in professional development, the goals are to support teachers in using a new curriculum, and in adjusting it to meet their own circumstances.

Any design problem of at least moderate complexity requires multiple areas of expertise. For example, Hoberman Toys is a small business making and selling a line of mechanical toys. As part of the design process, Hoberman utilizes the services of mechanical and manufacturing engineers, industrial and graphic designers, marketing professionals, copywriters (to create instructions), and even young children (to try out the toys). Each of these individuals makes an important contribution to the overall design process (Chuck Hoberman, personal communication, July 10, 2001).

In the same way, curriculum design and professional development design require diverse areas of expertise to address different aspects of these problems. Content experts, such as scientists and engineers, ought to play a role in defining the subject matter that students should learn. Writers, illustrators, and graphic designers might be helpful in presenting new curriculum materials in accessible, attractive formats. Staff developers and teacher educators may be able to engage teachers in trying out and evaluating new curriculum ideas. Teachers have experience in making concepts and capabilities become real in the classroom. Educational researchers can suggest methods for data collection and evaluation of curriculum and professional development designs. Each of these groups can contribute to a successful design effort.

Curriculum design for teaching technology has the advantage that everyone has experience with technology, as we pointed out earlier. However, familiarity with technology does not provide all of the background needed for the introducing it as a school subject. As with any other discipline, there are a number of core concepts that are fundamental to technology. Some of the organizing concepts of technology are inputs, outputs, systems, materials, information, energy, environments, controls, constraints, trade-offs, side effects, and failure. The most important processes in technology include brainstorming, scavenger hunts, classifying, sorting, data collection, data analysis, modeling, identifying needs, setting design goals, establishing design criteria, evaluation, troubleshooting, maintenance, repair, reuse, redesign, and communication. Professional development and curriculum should provide some guidance in these areas.

The key process of technology is design, but most people have probably never engaged in a conscious process of design. A lack of experience in designing is evident from the way design is sometimes taught. Design curricula are sometimes based on inflexible notions of how design is done, locking it into a prescribed "design method." Students who have designed something successfully are forced to pigeonhole the experience into the rigid categories of a design portfolio, making up steps they never actually did (McCormick, 1999). Real designs, including designs done by children, simply do not proceed in this way. Design is a messy affair, riddled with incomplete information, false starts, working backward as well as forward, solving part of the problem and then tackling the other parts, and so forth (Watts, 1991).

Whoever created a pre-ordained "design method" may never have done any design. To create and implement technology curricula, teachers, curriculum developers, and professional developers need first-hand experience in design. Here is another powerful reason for thinking of curriculum and professional development as design problems: it sets the stage for putting design into the curriculum.

Illustrating Collaborative Design: An Overview of the City Technology Project

City Technology is a project funded primarily by the National Science Foundation (NSF) to develop curriculum materials for teachers to support technology education in the elementary grades. This project is an outgrowth of a previous NSF-funded project, City Science, which was also based at the City College of New York, and took place from 1992 - 1995. Unlike City Technology, City Science was a professional development project that assisted 75 teachers from Harlem and the South Bronx in learning to use the urban environment as a major source of material for elementary science. Towards the end of the City Science project, we produced four curriculum guides outlining our experiences in developing ideas and strategies for teaching four areas of technology in the elementary grades. The titles of the four City Science Curriculum Guides are *Mapping*, *Mechanisms*, *Structures*, and *Environmental Analysis and Design*. The last of these guides deals with the organization of space and time in school environments, such as classrooms and cafeterias.

The City Science Curriculum Guides contained many innovative ideas, and provided an excellent record of the City Science project. However, these guides were not written in an accessible format that would help teachers adopt some of the ideas for their own classrooms. In order to produce materials that would be useful and could be published, we applied for and received an Instructional Materials Development grant from the NSF, which was the basis for the City Technology project. In the original conception of City Technology, we planned to revise the four City Science Curriculum Guides in the first year to make them much more useful to teachers. In the second year, we planned to add four new topics and write four new guides. As we shall see, these plans were quickly redesigned.

In our view, it is not possible to produce useful materials for teachers unless some teachers are partners in the process. To engage teachers as collaborators, we knew that we would need to develop a shared understanding of our basic approach to technology. Therefore, there had to be a professional development component to this project. However, the teachers had to be more than just students. Much of the thinking of project staff would need to be revised completely for the project to produce materials that would have some resonance with their audience. The teachers would need to have a major voice in the planning and direction of the project from the very beginning. As the project unfolded, they would have to play major a major part in developing, testing, and documenting classroom activities, and even in setting the overall direction of the project. As a result, the roles of the teachers in the project were complex and variable, and there was often a tension between meeting their professional development needs and fostering their full participation as partners in curriculum development.

City Technology was funded in April, 1997. Our first task was to recruit 25 teachers from local schools. About a third of this group had participated in City Science. The remaining teachers were recruited mainly by science coordinators from community school districts covering parts of Harlem, the South Bronx, and Washington Heights. Because of lack of time, this recruitment process was not well planned. Several of the new teachers conceived of City Technology simply as a professional development opportunity, and were not really prepared to do curriculum development, pilot testing, and documentation. Others found the time demands of the project to be too great. As we shall see, these factors led to a high attrition rate during the first year, which became the basis for redesigning the recruitment procedure for the second year.

The project began with a summer workshop for 25 teachers in 1997. The workshop was led by one of the authors (Benenson) and the other co-Project Director, Jim Neujahr from the City College School of Education. Three of the four topics planned for the first year were the topics of the original City Science Curriculum Guides: Mechanisms, Structures and Mapping. The fourth topic was the spatial aspect of Environmental Analysis and Design, which we called "Use of Space." Initially, we distributed copies of the City Science guides to all of the participating teachers, but few found them very useful, which was our first indication that the guides needed to be redone completely.

In the course of the City Science project, we learned to precede the July workshop with several pre-workshop evening sessions during June. This procedure has several advantages. It provides time for handling paperwork, introducing the topics, and distributing readings in a more leisurely way; allows us to run the intensive three-week summer workshop for four days per week instead of five; and offers teachers ideas for activities to try out immediately in their classrooms, during the waning days of the school year. We followed this same practice in City Technology.

The workshop structure was the same for each of the four topics. We conducted a one- or two-hour warm-up activity during the pre-workshop sessions in June. For example, the warm-up activity for both Mapping and the Use of Space topics began with a homework assignment: *Make a map of your desk or workspace*. During the workshop, we analyzed these maps to see the different ways people had chosen to represent three dimensions on a two-dimensional page, and to compare the kinds of features they had chosen to represent on their maps. The spatial environment activity consisted of using the maps to identify aspects of each workspace design that might benefit from a conscious redesign.

During the July workshop, the group met four days per week for three weeks. These began with what we called "extended activities," built upon the warm-ups, lasting about one day per topic. For example, the mechanisms extended activity consisted of analyzing common mechanisms, such as umbrellas, vise grips, and folding chairs, and making cardboard models of them. At some point during the day, a staff member made a brief presentation of the "big ideas" or key concepts related to the topic, using examples that had already arisen during the activities. For the mechanisms topic, these concepts included input and output; lever, link, joint, and linkage; fulcrum, effort, and load; the law of the lever and the concept of mechanical advantage; and first, second, and third-class levers.

In the third phase of the workshop, the teachers divided into groups according to which of the four topics they wanted to explore in greater depth. After spending several days conducting their own investigations, each group had to come up with an activity for every participant to do. The Mechanisms group, for example, developed a "Lever

Scavenger Hunt" activity, which was structured as a game. Each of the other groups had to find and label first-, second- and third-class levers anywhere in the workshop area, including obvious examples such as scissors and pliers, but also more subtle ones like doors and faucet handles.

During the final week, all participants were asked to write down activities and curriculum ideas that they thought would be appropriate for their classrooms. These suggestions were assembled into a "Big Idea Book," which became the starting point for pilot testing during the following academic year.

An issue arose during the first workshop that illustrates the tension between the professional development aspect and the curriculum development focus of the project. During the period of independent group investigations, the Structures group decided to design and construct a table and set of chairs. Their design required them to spend many hours repetitively weaving slats together with string. When project staff members questioned the group about the educational value of this activity, the group responded that their goal was to complete the product, and the staff should let them achieve this goal. The ensuing discussion was framed as "process vs. product." In retrospect, the staff felt that these issues should have been handled by referring to classroom outcomes, not the workshop, and the ways these outcomes should be reflected in the curriculum guides.

During the 1997-98 academic year, the teachers were expected to try out activities from each of the four topics in their own classrooms, and to document the outcomes. They participated in biweekly evening workshops to support this process of pilot testing and documentation. These workshops had two components. There were new activities for the teachers to do and reflect upon, to supplement those in the Big Idea Book. We encouraged the teachers to modify these activities for their own classrooms, or invent new ones better matched to their own teaching situations and to their children's interests. Second, we provided time for the teachers to share their classroom work, and exchange ideas about what had worked and what hadn't.

The sharing sessions provided both the staff and the teachers with valuable insights about the feasibility of various activities in classroom settings, and ideas for entirely new activities. For example, one teacher reported on a mapping activity she had developed as part of a museum visit. She had made multiple copies of the museum floor plan prior to the trip, and then asked her students to plan their route within the museum using these maps. After the trip was over, the students examined the printed maps critically and came up with ways they could be improved. This idea became very popular. Several other teachers tried variations of it in their own classrooms, and reported on the outcomes in subsequent workshops.

Each teacher was also asked to produce a portfolio of her classroom work related to the project. Twice during the year, project staff met with each individual to review this portfolio. The portfolios included the following items:

1. Lesson worksheets describing the activities and units implemented in the classroom, including materials used, teacher tips and strategies, and assessment methods;
2. Narrative descriptions of what actually happened in the classroom;
3. Samples of students' work, including writing, maps and drawings, and dialogue; and
4. The teacher's own reflections on the activities.

For some of the participants, the portfolio review sessions became occasions to evaluate their participation in the project, and some decided not to continue. For others, the sessions were opportunities to discuss their ideas, solicit suggestions, and contribute to the progress of the project.

By the end of the year, about half of the original group of teachers had left the project and ten additional teachers were recruited to replace them. Based on the experiences of the first year, however, we redesigned the recruitment method. Some of the new teachers were recommended by teachers already in the project, while others were sent by their districts. Every prospective participant had to be interviewed by a team that included one of the continuing teachers. The teacher member of the team was generally the most explicit about the nature of the commitment, and the time and effort needed for the project. As a result, the process was much more selective, and the second-year group came with a much better understanding of the project.

In consultation with the some of the first-year teachers, we identified four new topics for the second year: Physical Controls, Containers and Packages, Signs and Symbols, and the non-spatial aspects of Environmental Analysis and Design, which we called Social Controls. The second year began with a summer workshop preceded by evening pre-workshops in June. As in the first year, we conducted a warm-up activity for each topic during the pre-workshops. Between the pre-workshops and the regular three-week session, we asked each participant to develop an independent investigation at home or school related to one of the four topics. These investigations were very fruitful. For the topic of Packaging, for example, one teacher did systematic product testing of shopping bags by recording the amount of weight each bag could hold before breaking. Then she examined how different kinds of shopping bags actually gave way. This became one of the most popular City Technology activities.

A moment of epiphany came for the project staff during the design of an activity for the Social Controls topic. The following activity was proposed: *Design a new schedule for all three weeks of this workshop*. This suggestion created a dilemma for us as professional developers, because it would require us to relinquish control over the workshop schedule. However, as part of the City Technology curriculum, we wanted teachers to engage their students in redesigning classrooms and classroom practices. To do so, they would have to consider sharing some of their own classroom design problems with their students. Therefore, we ourselves had to experience how it felt to share some control with others, and we had to model this kind of "letting go" for the teachers. In the end, we did conduct this activity, which resulted in some significant modifications of our original workshop agenda.

The academic-year workshops also followed a similar format to those of the previous year, except for one major innovation, which was proposed by Terri Meade and Dorothy Bennett, the Research Team from the Education Development Center. Instead of the individual portfolio reviews, we held a "Portfolio Roundtable" at the end of each semester, where each teacher presented her portfolio to the entire group. These sessions made the portfolios much more public, and contributed greatly to the exchange of ideas. They also served as a model for group assessment of students' work. At the end of each presentation, all participants were asked to contribute first "warm" comments, highlighting what they had liked about the portfolio, and then "cool" ones, expressing questions, doubts, or criticisms. An example of a warm comment was "I especially like the way you made the City Technology topics into integrative year-long-themes." The cool comments were mostly expressed as questions. A typical one was "How did they collect and report data" (Benenson & Nejuahr, 2001a)?

Conceptual problems with some of the topics emerged during the second-year workshops, and these affected our thinking about the guides. Several teachers felt that project staff had failed to define words like "control" clearly enough, leaving considerable room for confusion. For example, one teacher maintained that a wall is a control, because "it controls where you can go and where you can't." We therefore decided to combine the topics of physical controls and mechanisms into one.

During the first year of City Technology, we had decided to divide the City Science topic Environmental Analysis and Design into two topics, Social Control and Use of Space. However, in retrospect, we felt that this dichotomy didn't work. For one thing, we hadn't defined the Social Control topic clearly enough, and some teachers had interpreted it very broadly to include areas that had little to do with schools, and that did not offer opportunities for design. We wanted this topic to include classroom procedures, practices, and schedules that could be subject to analysis and redesign by students. In addition, we realized that problems of this nature often include both the spatial environment and the more amorphous environment of rules and schedules. For example, redesign of a school cafeteria typically requires changes in lunch schedules rearrangement of furniture, garbage cans, etc. For these reasons, we reverted to the original idea of combining these topics into one.

Another conclusion from the pilot tests was that we needed to rethink the topic of Structures. A variety of other curriculum efforts have introduced this topic by engaging students in building model bridges and towers, and we did not want to duplicate their efforts. Besides, one theme of City Technology is that design problems should focus on the students' own problems, so we shifted the focus of this topic to useful classroom structures, such as shelves and storage units. The materials available for making these structures usually come from discarded packaging material. Also, every package, such as a shopping bag or a carton, is also an example of a structure, and many of the principles of structures can be learned by seeing how these items fail. For these reasons, we decided to combine the topics of Packaging and Structures.

The workshop experiences and portfolios produced in the first two years became the basis for writing draft versions of five curriculum guides. During the 1999-2000 academic year, the five draft guides were field-tested at five sites, including two in New York City, one in the New York metro area, and one each in Michigan and Nevada. To prepare for the field tests, eleven professional developers from the five sites attended a summer institute in 1999 to engage in sample workshop activities and develop strategies for conducting workshops at their own sites. For each of the five topics, a teacher who had done pilot testing presented her portfolio to the group to provide concrete examples of classroom implementation.

The following academic year the professional developers led workshops to introduce the guides to teachers in their own regions. About half of the nearly 100 workshop participants agreed to field-test the City Technology activities in their own classrooms and to document their experiences. Data from these field tests informed the final revisions of all five guides. These revisions included complete rewriting of several chapters of each guide, addition of Literature Connections for each topic, new material on assessment, more uniform presentation of activities, and an expanded discussion of national standards.

One of the most difficult design problems was coming up with a more engaging series title than City Technology. We put this problem to a group of teachers and professional developers who had been involved in the project, and the best suggestion was: *Stuff that Works*! The *Stuff that Works*! series now includes the following titles: *Designed Environments: Places Practices & Plans* (Benenson & Neujahr, 2002d), *Mapping* (Benenson & Neujahr, 2002e), *Mechanisms & Other Systems* (Benenson & Neujahr, 2002a), *Packaging & Other Structures* (Benenson & Neujahr, 2002b) and *Signs, Symbols & Codes* (Benenson & Neujahr, 2002c).

The first chapter of each guide, "Appetizers," presents activities that a teacher can do for herself to become familiar with the topic. These activities arose directly from our experiences in the workshops, and many of the ideas came directly from the Big Idea Books. The second chapter of each book, "Concepts," reflects the successes and failures of project staff in presenting the basic ideas about each topic during the course of the workshops. The next chapter contains classroom activities, all of which have been tried out by teachers in their own classrooms and documented in the portfolios. Many of the teachers' narratives, samples of student work, and reflections are collected in "Stories," Chapter 4 of each guide. The final two chapters, "Resources" and "Standards," use examples from "Stories" to illustrate a discussion of assessment, and to demonstrate alignment with national standards in technology, science, math, English language arts, and social studies.

The external evaluation of the field tests suggested that many of the teachers at the five field-test sites saw the value of the *Stuff that Works*! materials. The evaluators summarized their findings as follows:

> Data from the national field-test of the City Technology Curriculum Guides suggest that these materials fill a need and are valuable to a variety of teachers around the country. A range of teachers volunteered to test the CTCG activities and concepts in their classes. These educators represented grades K through 8; urban, suburban, and rural school settings; and a continuum of experience levels from first year teachers to 20-year veterans. In surveys, portfolio writings, and portfolio roundtable discussions, field-test teachers reported that CTCG materials were extremely or very useful to them. Particularly, they noted that the activities served and challenged all of their students: guide activities motivated under-achieving, ESL, and special education children and provided them with opportunities to excel. At the same time, the activities challenged and engaged accelerated students in the class. (Bennett, Tsikalas, & Meade, 2000, p. 53)

Perhaps more revealing than these general conclusions are the reflections of individual teachers who participated in the field tests. Some of their comments included:

> The strengths of this unit are the opportunity to group students, work on communication skills, problem solve … and plan real life tests. I have watched my students go from asking simple yes/no questions to thinking and planning careful, thoughtful active questions. The students began to see each other as people with answers … I was no longer the expert with all the answers.

> At second grade, with basically no prior knowledge of mechanisms, I wanted the students to start to analyze/take apart objects around them … Most of my students really enjoyed working with mechanisms. I noticed that more girls participated in discussion than with some of my previous science activities.

> I must begin by telling you that I found this particular guide to be so much fun and the students demonstrated so much energy and interest in this area … I was able to engage them in the activities easily

> … The activities were very educational and provided so much vital information that helped students connect what is being taught to them in math to real life situations, e.g., graphing behavior and using tallies to record information. For my [special education] students, I found this gave them self confidence …
>
> I read the entire guide from front to back … Although the main idea of the unit is not specifically a large focus of instruction in our fourth grade curriculum, I recognized the power behind the ideas and activities and knew that this unit would promote collaboration, problem solving, and communication … Overall, I think my students loved this unit and felt enormously successful after we finished …
>
> My most important goal for students is that they feel good about themselves and realize what they can do. I liked these activities, because they had these results.

By the end of the project, a common theme developed among all of the project participants, including college faculty, educational researchers, and teachers. We all came to see each of the problems we confronted as yet another design problem. For example, modifying an activity so that it would be appropriate for an early childhood classroom was a problem in redesign; finding appropriate materials was part of a design problem; and deciding on a format for teachers' portfolio presentations was a design problem. By its nature, each design problem had to draw on the expertise of all of the participating groups. Thus, the theme of design became the glue that held the project together.

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