DOCUMENT RESUME

ED 297 708 IR 013 412

AUTHOR	Martin, Laura M. W.
TITLE	Teachers' Adoption of Multimedia Technologies for Science and Mathematics Instruction. Technical Report No. 40.
INSTITUTION	Bank Street Coll. of Education, New York, NY. Center for Children and Technology.
PUB DATE	Jun 86
NOTE	28p.
PUB TYPE	Reports - Research/Technical (143)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Adoption (Ideas); Computer Assisted Instruction; *Computer Simulation; *Discovery Learning; Educational Television; Elementary Secondary Education; Inservice Teacher Education; Instructional Development; *Instructional Innovation; Intermediate Grades; Mathematics Instruction; Microcomputers; *Multimedia Instruction; Science Instruction; *Teacher Role
IDENTIFIERS	Mathematics Science Tech Teacher Training Proj NY

ABSTRACT

This report describes a training project undertaken as part of the Bank Street College Mathematics, Science and Technology Teacher Training Project (MASTTE) to introduce teachers to "The Voyage of the Mimi," a 13-part television drama and multimedia package designed to supplement the regular curricula for science and mathematics in the upper-elementary and middle school grades. A major focus of the discussion is the effectiveness of the Mimi materials for classroom use, i.e., four microcomputer modules with manuals and a book version of the television show with classroom activity suggestions and additional factual information. The effects of the organizational features of the individual school systems on the adoption and diffusion of these materials are also discussed, using the notions of multi-entry levels of technology and embedded context analysis to help describe and understand the factors affecting classroom change mediated by the introduction of technology. It was found that teachers were able to tolerate a wide range of conditions for working with the Mimi package, and that the teachers' work in the classroom seemed to be as much influenced by the technology as the technological applications were shaped by the teachers. Finally, it was also found that the school systems significantly influenced and defined the project goals for the teachers, so that individual experimentations by teachers in the classrooms had different impacts depending on the context of the wider systems in which they occurred. (17 references) (EW)

TEACHERS' ADOPTION OF MULTIMEDIA TECHNOLOGIES FOR SCIENCE AND MATHEMATICS INSTRUCTION

Laura M. W. Martin

Technical Report No. 40

June 1986

TEACHERS' ADOPTION OF MULTIMEDIA TECHNOLOGIES FOR SCIENCE AND MATHEMATICS INSTRUCTION*,**

Laura M. W. Martin

Applying Technologies to Science and Mathematics Instruction

At present, there is a great deal of national concern about the quality of science and mathematics instruction, particularly in elementary and middle schools. Because science is rarely well integrated into the curriculum, many children lose interest in this subject early in their school careers. In both science and mathematics, the material covered often appears to be both irrelevant to the students' daily life and not intriguing enough to study for its own sake. The teachers themselves are often underprepared and uncomfortable with teaching basic concepts.

In recent years, curricular goals in these domains have been undergoing change. Science and mathematics educators have been calling for a problem-solving approach (National Council of Teachers of Mathematics [NCTM], 1980; National Science Teachers Association [NSTA], 1982). In the case of science, this means greater emphasis on scientific method and on ways to motivate inquiry and investigation among children; in the case of mathematics, motivation and more flexible use of concepts are the hoped-for outcomes. Educators recognize that preservice and inservice training for teachers will have to reflect this new emphasis in the near future (NCTM, 1980; NSTA, 1983).

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*To appear in Pea, R. D., & Sheingold, K. (Eds.), Mirrors of mind: Theory, research, and development from Bank Street's Center for Children and Technology. Norwood, NJ: Ablex.

**This chapter is based on work carried out by the research staff of the Bank Street College Mathematics, Science, and Technology Teacher Education Project, directed by Regan McCarthy, with resources provided by the National Science Foundation. The contributions of Mary McGinnis and Maxine Shirley to the research process were invaluable. The insights shared with us by the project training staff, Marilyn Quinsaat and Bill Roberts, and by the classroom teachers are also gratefully acknowledged.

While materials that deal with science and mathematics in enriched ways have been available for some time, they have not taken hold in all or even most schools. Materials alone do not seem to solve the problem of teacher adoption of new methods (Berman & McLaughlin, 1978). However, as we have pointed out elsewhere (Sheingold, Martin, & Endreweit, in press), the advent of new technologies is likely to provide leverage for school change in a way that hands-on science kits and problem-solving games do not, if only because of the enormous interest they have for educators, parents, and students.

Two concepts have been particularly useful in the analysis and understanding of the technology-adoption process in schools. The first calls attention to the technology itself, for its ability to provide multiple levels of entry to the teachers and students who use it (Levin & Kareev, 1980). A technology that provides different routes for accomplishing the same activity can accommodate a range of individual approaches to problem solving. The second concept calls our attention to the broad and complex contexts within which learners, teachers, and technology function. This "embedded context" analysis requires us to look beyond an individual child's carrying out a particular task in order to understand how learning is supported and tasks are carried out in the classroom (Laboratory of Comparative Human Cognition, 1985). These two notions--multiple-entry level technology and embedded context analysis--can help us to describe and understand the factors affecting classroom change mediated by the introduction of technology.

Multiple Levels of Entry

The idea of offering several paths into an activity means that both the expert and the novice can use a software program for their respective purposes, which, in some cases, is accomplished by building levels of complexity into the program. For example, with certain software, once a set of parameters becomes comfortable for the user, s/he may select more complex options that provide corresponding gains in program control or flexibility. In other cases, multiple entry into an entire medium, such as the microcomputer, may be designed. The different kinds of user participation required, for example, by a computer-assisted instruction (CAI) program and by a turtle graphics environment result from different amounts of user support or program structure. In a classroom, a range of structure may suit the needs of different users of the same computer (Riel, Levin, & Miller-Souviney, 1984) or the different needs of the same user.

The Voyage of the Mimi materials, created at Bank Street College, are an example of technology designed to accommodate the multiple needs of people. This system distributes access to potentially instructive experiences across different media. We will examine how such a system can contribute to the particular goal of making science and mathematics relevant to both teachers and their students.

The Embedded Contexts of Learning

The second notion that has import for the technology-adoption process is the understanding that learning tasks may be viewed as occurring within embedded contexts, each of which influences performance on the tasks (Laboratory of Comparative Human Cognition, 1985). On a simple level, one can document that a teacher's use of a microprocessor is often determined by the routes through which machines are introduced (e.g., by a teacher-enthusiast) into the classroom (Hess & Miura, 1984). Less directly, institutional factors have been seen to exert influence at the individual level on decision making about children's educational needs (Mehan, 1984a). Thus, in order to understand adoption of educational technology that appears to depend on teacher attitudes and experience, it may be necessary to analyze the process as part of district "organizational procedure" (Mehan, 1984a), rather than as teacher choice. In this regard, the current work points to district procedures that are influencing the use of technology by individual teachers in their classes.

In order to specify how district procedures influence classroom change, we look for the presence of support for teacher learning as it becomes structured in the context of a more comprehensive goal, usually formulated at the level of the district. The larger goal will necessarily have an impact on technology adoption by defining what constitutes feedback and support.

The current framework is consistent with what studies have found to be factors relevant to the adoption of innovation in schools (Berman & McLaughlin, 1978; Hord & Loucks, 1980). As we shall see, the themes of multiple-entry points and embedded context allow us to describe the initial stages of a developmental process which took place among individual teachers attempting to improve their classroom practices through the use of educational technology, and among districts attempting to improve instruction across schools.

This chapter reports preliminary findings from a training project that introduced teachers to The Voyage of the Mimi, a multimedia package for teaching science and mathematics. Some of the assumptions behind the development of the package and the goals of the teacher training are described as they address current concerns about science and mathematics instruction generally.

"The Voyage of the Mimi" Materials

We begin by providing background on The Voyage of the Mimi materials and the related Mathematics, Science and Technology Teacher Education Project (MASTTE), and then briefly describe the results of the training program. The major focus of the chapter is a discussion (1) of the effects of the various media that comprise the Mimi materials on classroom instruction, and (2) of the effects of the organizational features of the school systems themselves on the adoption and diffusion of these materials. The concept of multiple-entry level technology helps us to understand the first set of effects, while the notion of embedded context is useful for understanding the second.

In 1981, with funding from the U.S. Department of Education, the Bank Street College Project in Science and Mathematics began the development of a multimedia program using video, computer, and print that was aimed at helping children gain a better understanding of science, mathematics, and technology. This program, The Voyage of the Mimi, has been available on the commercial market since the spring of 1985.

The designers of The Voyage of the Mimi worked from several conceptual premises which addressed the issues of what would stimulate change in science and mathematics practices in the schools. These premises related to the effects of the media on users, both teachers and children.

First, the developers were concerned with providing the children with concrete and affective experiences, and then moving to more abstract activity. As a result, the centerpiece of The Voyage of the Mimi is a 13-part television drama that portrays the adventures of a group of young scientists who are studying whales off the coast of New England. During the course of the show, viewers see the crew conducting scientific "experiments" and solving technical problems. Each episode is accompanied by a documentary showing scientists engaged in their work, thereby offering students and teachers a chance to apply their "story" involvement to a real problem domain.

Four different computer modules covering concepts related to the scientific voyage allow children to experience simulation of navigation instruments, a microworld ecosystem, a tool for measuring and graphing physical events, and a programming environment. Although researchers are only beginning to study the effects of these types of computer-mediated experience on learning outcomes, it is presumed that such activities on a microcomputer give children experience in linking concrete and abstract problem dimensions in ways otherwise unavailable in classrooms. For example, the Whales and their Environment module includes hardware and software that allows a microcomputer to measure and record temperature, light, and sound. The possibility of relating measurement and representation of measurement directly with the laboratory tool accompanying the Mimi provides special connections that are not readily demonstrated with graph paper and thermometers.

The Mimi package includes a book version of the television show with classroom activity suggestions and additional factual information, as well as books to accompany the microcomputer modules. The latter present information related to the module content, computer-based and noncomputer-based activities. Thus, the print materials both iterate information available from the video and microcomputer, and in some cases present new facts, experiments, and puzzles. In many instances, the specific activities available through the print materials make a bridge to the recording and interpreting of information and to the use of notation systems, both central to science learning.

Second, because of their belief in the importance of demonstrating to children the social nature of doing science, the Mimi developers showed people working together, provided materials that allow children to work cooperatively and productively in their thinking, and presented open-ended topics that are of interest to both scientists and children. The developers assumed that the fact of shared questions and interests would become an important part of the discovery experience for the children; for example, very little is known about whales, and it was found that a large cross-section of children are fascinated by these mammals.

Third, the Mimi package takes into consideration the teacher's participation in the enactment of science. Designed to be supplementary to regular curricula, the Mimi materials contain no scope or sequence requirements or suggestions. At the same time, however, a teacher's manual gives suggestions for activities in class, discussion topics, vocabulary, and work on concepts related to the Mimi themes in ways that are designed to broaden teachers' notions about science and mathematics. Information about whales is also provided for the teacher in the manuals; no assessment materials are. More importantly, the materials were designed to establish an exciting context and reason for teachers to teach science and mathematics, something not ordinarily available. As one teacher described her typical science lesson:

> I had a book with questions and an experiment to answer each one. "What is the purpose of a reservoir?" Then you have them build a reservoir and figure out the purpose. That's the curriculum. Six or seven questions per unit.

The Mimi materials, in contrast, invite the teacher to be an active explorer in the learning situation by being responsible for much of the organizational and motivational work, which is dependent on technological tools.

The MASTTE Project

Although the materials were designed to be implemented by teachers without specific training, and since this was the first commercially available package of its kind, it was not apparent what pattern of activities would develop in the classrooms of the teachers who used them. The designers felt that it would be important to support their innovative program by specifically training teachers to make the most of the integrated media and subject matter.

The Bank Street College Mathematics, Science and Technology Teacher Education Project (MASTTE) was undertaken in order to address the needs of teachers using The Voyage of the Mimi. Its purpose was to develop a training model for upper-elementary and middle-school teachers that would focus on the use of new and old educational technologies to promote science and mathematics instruction.

The training was designed to meet teachers' personal needs for an explanation of the concepts and materials in the Mimi package, for models of appropriate pedagogical methods, for ideas for handling changes in classroom activity, and for building broader systemwide adjustments to the new program. During its first two phases, the MASTTE project utilized a combined workshop, demonstration, and discussion format for a week of training, and provided participating districts with support after training in the form of site visits and phone contact with Bank Street field staff.

The MASTTE Research Program

In the spring of 1985, researchers from the Center for Children and Technology began to look at what was being accomplished by teachers and district personnel in their schools as a result of their training experience, and at the factors that might be influencing implementation of the materials and program. Further, in an effort to determine the extent of the information made available by each technology in instructional situations, the researchers asked about the nature and content of the activities that were being conducted, whether the activities were consistently utilized in all classes, and what elements made districts judge the program worth continuing.

Between March and June, the research staff of the MASTTE project visited each of 16 classes an average of four times. Structured observation forms were used in the classes, and field notes were taken. All teachers and staff developers were interviewed towards the end of the school year. The two Bank Street field trainers who were providing support for the districts were asked to maintain logs describing each of their site contacts in participating districts. The Bank Street staff were periodically interviewed by the researchers.

Many issues concerning science and mathematics instruction arose as a result of the first phase of our work (March through June, 1985). The focus here, however, is on the technology: how it was seen to influence what was done in classrooms, and what in turn influenced its use. General and specific patterns that emerged in this sample of classes will be described, and some reasons for the patterns offered.

MASTTE Training Week Participants

In February of 1985, during the first phase of the MASTTE Project, 16 classroom teachers (grades 4, 5, and 6) and ten staff developers from four New York area districts were introduced to The Voyage of the Mimi in a week-long training session.

A pretraining questionnaire surveyed the participants' general teaching experience and technical background, as well as their views about instruction. The average number of years of teaching experience among participating teachers was 14; staff developers averaged 17.2 years. All participants had taken more college courses in science than in mathematics, with only five teachers and two staff developers having taken mathematics in college. The staff developers had more experience with computers than did the teachers, six having taught computer work to others.

According to their responses on the questionnaire, teachers and staff developers had different views of the need for schools to improve science and mathematics programs. Teachers tended to stress availability of resources; for example, the need for more lab equipment and teaching kits. Staff developers' perceptions were varied, with some consensus that teachers needed more hands-on experience in order to improve programs. Methodological and support structure needs were rarely mentioned.

Later, in an interview, one teacher expressed a basic dilemma:

> I never had to teach elementary science and I was bored with it. The curriculum they give you--no books, not a reference material--you have to find everything. Then you have to put it at a 3.6 reading level. It's frustrating. By

> then, you don't even want to do it any more....When I said science [to the children] it was boredom.

Results

The Impact of the Program on Teachers

All 17 teachers and nine staff developers in the first phase sample, regardless of background, were highly pleased with the materials, in large part because the format allowed an entry point for everyone. As one teacher put it: "I find the materials very useful and they suit my style of teaching. But my style is not everybody's style."

The open-ended nature of the materials related directly to the teachers' abilities to reach the students. One teacher expressed it this way: "With the variety of materials, they're able to reach every kid, whereas before, if you used one type of material you were not reaching everybody." The teachers whose schedules allowed them to choose when to teach science (all but two) reported that, as a result of participating in the MASTTE project, they were teaching more science in their classes. At each site, it was decided that classes would visit the aquarium, the natural history museum, beaches, and marinas. School librarians, computer teachers, science teachers, art teachers, and parents became involved in providing support for the project. Principals in each district reported that their veteran teachers were newly inspired by working on Mimi activities. Children who had never before shown an interest in science, or indeed, in a couple of cases, in school at all, were fascinated by the Mimi. A fifth grade teacher reported of one child: "all of a sudden his mother said he's interested in science, he wants to be a doctor...he wants to go into research."

In class after class, we observed and heard of virtually 100% time-on-task for the whole class during Mimi lessons. Teachers felt that since the video showed the functional context of the scientist's task, it motivated the children to ask questions and provided a framework for the teachers to arrange experiments and activities. One teacher reported her surprise at the children's eagerness to see the documentaries; they felt that the programs "answered some of their questions."

Other teachers emphasized the significance of these materials for showing children a fuller context for asking scientific questions and for using problem-solving tools:

> I was surprised they got some of the concepts that they did, like hypothermia...since they are fourth graders. We

> did convection and conduction, and when I tried to do that earlier with the science textbook, it was impossible.

It is clear that the teachers were highly reinforced for their efforts by student attentiveness. Children even volunteered for extra work; they gave up gym, art, lunch, recess, and before- and after-school time to do science activities. "I've had them actually say to me, 'Can we skip art and continue with the Voyage of the Mimi'!"

These are indeed powerful materials. Considering the demands placed upon the teacher by the multimedia format--utilizing new technologies in new ways, arranging experiences of scientific process, and tackling subject matter in new contexts--it is clear that they can be motivated to engage in a complex process of change. We conclude that because of the features of multiple-entry level inherent in the current approach to material and training, the demands on the teachers we observed were likely to be regarded by them as manageable, even revitalizing. It is not surprising, therefore, that every district planned to expand its use of the materials during the next school year.

The Effects of the Integrated Media on Instructional Situations

An assumption of the developers of The Voyage of the Mimi was that each of the media employed in the program would provide a unique channel for information to reach the children. Less articulated were assumptions about the effects of the media on lesson organization. Despite schools' typically inflexible science and mathematics lesson structures (whole-group learning and individual "seatwork"), segmented (as opposed to integrated) curriculum, and set time periods, the technological vehicles of the Mimi package affected the social arrangements of learning. In fact, some of the most interesting results of our observations pertained to these effects. Moreover, they have profound implications for the availability of information in classroom settings. Video, computers, and print materials offered teachers a choice of how to introduce science and mathematics content. This multiple-entry system supported the teachers in the early stages of developing teaching objectives to promote inquiry and to integrate science and mathematics. The media held the interest of children and teachers alike as teachers began to assimilate, or "own," the goal of stimulating children's curiosity and knowledge.

Television

In the middle-school years, the impact of televised information can be as powerful as 3-dimensional experiences are for younger children. Because the children can comprehend visual narrative and because they learn from modelled behavior, they seem to remember and to be very attentive to what they see on the video screen (Greenfield, 1984). Children can readily access science and mathematics concepts and problem-solution strategies when they are presented in a televised format. As one teacher commented: "Certainly watching something about whales, watching it on TV, is just wonderful. Going from concrete to abstract...it took over the lesson much better than I could do." Another teacher observed:

> I saw them sitting there in that room today, looking as if they were there...you're not smelling the salt air, you're not touching [a whale], you're not even on a ship...but I think they're there. The viewing was far more of an experience for them than it was for me.

Referring to the video episode in which the captain of the vessel Mimi develops hypothermia, another teacher remarked:

> Why do these kids get so involved in hypothermia? That's because that's CT's [a character's] grandfather that's lying there unconscious on the beach. They're totally involved in that. It could be their grandfather or friend or parent ...and that's where TV has it all over a book....[referring to the documentary accompanying another episode] You could read about Mt. Washington until you're sick of reading it, but...when Ben [the actor who plays CT] is knocked over and cannot walk because the wind is so strong and the meteorologist has to grab him, that's more graphic than anything you ever read....I think TV is great.

The teachers we observed held different theories about television's contribution to education. A couple felt that video was not the "concrete" experience that the developers were claiming it to be: "It's recreational; reading is educational." Another, describing what was a widely reported phenomenon said:

> When they [the students] go to the reading and the words [after seeing the video], they recall far more than I thought they would, and it makes the reading more interesting...they want to take the books home.

Television was used as a motivator and tool, as a lesson text, and as a reward, according to what teachers felt the video could accomplish. Some teachers noted that "viewing interest is intense even at the second viewing" and "my kids act as if it's a reward," but one felt that

> to see the Voyage of the Mimi for a second or third year, I would have trouble with that. Even theoretically, yes, they could get things that they missed the first time. I think it would be too costly, time-wise.

Yet, despite the range of attitudes, the video was used regularly and its use regularly caused changes in learning arrangements. When members of the research team visited the MASTTE classes, they were most often shown a television-viewing and discussion session. The reasons for this may lie in what teachers thought the visitors expected, or in the fact that teachers may be more comfortable conducting this type of lesson. However, what was most striking in these sessions was the rapt attention of the children during the viewing and the subsequent discussions.

During those lessons that were configured around the video segments of the Mimi, shifts occurred to change the usual patterns of lesson organization. First, chairs were pulled out of alignment and grouped closely together. Second, children sat or draped themselves on the chairs or desks in relative disarray, rather as if in a living room. In many classes, children would consistently get their Mimi books out without teacher direction in order to follow the video. This kind of informality was also reflected in the class members' interactions. The usual turn-taking and discourse patterns were often disrupted; the teacher and the children talked over the video, commented (not just answered or asked questions), and failed to bid for the floor in the style that generally characterizes a lesson. Informal interactions occurred even in cases where teachers did carry on formal questioning during the video sequences, sometimes stopping the machine in order to pose questions to the students. However, when video viewing took place in the auditorium, little informality was noted.

It may be that the relaxed or home-like features of television viewing have learning implications for children who are not at ease with the classical whole-group, teacher-led lesson format. Television viewing may encourage more open-ended exchanges, more personal involvement in the material, and a less teacher-centered focus, all of which may contribute significantly to children's learning. It has also been suggested that if the television channel carries the "facts," the teachers may be freed to ask the children other kinds of questions (John Black, personal communication, 1985).

Microcomputer Modules

While the use of television in the classroom was a new experience for some of the teachers, the microcomputer was for all both a novel teaching tool and an unfamiliar medium. During the training period, the teachers' reactions to computers ranged from eager to amused to hesitant, and all but one learned to use the software.

The Voyage of the Mimi modules that were available to the teachers--Introduction to Computing and Maps and Navigation--were not equally utilized. Based on Logo, Introduction to Computing incorporates prompts which the developers felt would help children to understand the features of the programming language better than does a free Logo environment (Hawkins & Kurland, in press). In schools that had a Logo curriculum already in place, the teachers did not see the advantage of the module (except, in one case, for use with young children not yet using Logo), despite their positive comments about how the software could facilitate work with programming concepts. One lab teacher, however, regularly used the software, even in non-Mimi classes. The fact that teachers who were not familiar with Logo also tended not to use the module might be accounted for in two ways: First, this module was not as strongly emphasized in the training week as was the Maps and Navigation module. Second, with the exception of two Whale Search games, the module's programming exercises were not as clearly integrated with the Mimi content or with the reading matter on computer history. Teachers recognized that this software did not build directly upon concepts in the show.

The Maps and Navigation module, in contrast, was used in all classes. It clearly created junctures for teachers and children to interact around Mimi topics by demanding the use of certain concepts within the "whole task" (Mehan, 1984b) of the navigation game. The children in the classes we studied willingly gave up such activities as recess, lunch, art, and gym for chances to play the simulation games, and thus came in contact with the educational opportunities believed to exist there. One teacher said:

> I'm supposed to be teaching them some foreign country in social studies. I found out nobody in this class knew anything about geography. Well, we're not going to any foreign countries till we know how to get there. And this particular navigation thing is perfect for me.

Maps and Navigation is made up of three navigation games designed to teach latitude and longitude, speed/time/distance calculation, and triangulation with a radio direction finder. A fourth game in the module, Rescue Mission, simulates a navigation problem whose solution depends on students' coordinating their use of a variety of "instruments," as well as a map and a parallel ruler, and on choosing their procedures in a strategic sequence. The games are designed to be played in teams.

Teachers have reported that children have gained fluency with the concepts embedded in the games, although direct instruction about rate calculation, measurement techniques, and reading screens appears to be necessary. Another outcome concerns the organization of learning partners that occurred when children used the software. While the introduction of the machines did not cause any of the MASTTE teachers to reorganize the physical or temporal arrangements that were in place for lessons (see Mehan, 1985), several teachers felt they could tolerate "noise" and so allowed pairs of children to play navigation games while others in the class worked at their seats. Also, teachers who demonstrated how to use the computer in front of the class sometimes had children assisting at the keyboard or reading the screens ("When I introduce a game, I'll do all the different techniques that they need and then I'll let them work on it").

Since all the teachers taught whole-group lessons and this did not change, and since the computers were used, this meant that small groups of children were allowed to use the computers primarily during free time, that is, lunch, recess, and before and after school. Only occasionally did certain teachers allow pairs of children to work at the computer during whole-group lessons. Both for those who planned some computer use during their lessons and for those who didn't, novel peer configurations at the computer were noted. "I let my brighter ones work on it first, and then when they've mastered it, I mix up groups." Either by design or spontaneously:

- boys and girls were seen to work together for the first time;
- more experienced children taught less experienced children;
- "quicker" learners worked with "slower" learners;
- children paced themselves, recording their own activities;
- children distributed tasks cooperatively, for instance, taking the role of keyboarder, scribe, or strategist.

Interesting shifts in thinking occurred for some teachers who used the computer in front of their classes. During a training discussion on inquiry lessons, one teacher made clear his view that teachers must know all the answers before conducting a lesson. As a result of his making errors while demonstrating the use of the computer for his class, he later told his colleagues in the district about the value of "learning along with the kids." Two teachers who controlled the computer in whole-group lessons reported that they were using computers at home for the first time as a result of getting familiar with the machine in school. A staff developer reported that an experienced teacher asked for advice after an unsuccessful lesson: "I think the fact that teachers are open to changing their ways of teaching is really admirable for people who've been in the system for a long time." Thus, although the essential structure of the lessons did not change, the computer caused changes and reexamination of social arrangements within the familiar structures.

Print

In contrast to the novel arrangements generated through the use of the video and microcomputer, the lessons organized around the Mimi print materials were consistently traditional. Specifically, we saw lessons in which children each took a turn to read a paragraph; children followed along with the teacher; children looked for answers to the teacher's questions in the text; children were instructed to do the activity in the book; children were instructed to answer the questions in the book.

We may suppose that for teachers the children's books, the teacher's manual, and the computer software guidebooks all represented a familiar school format, and thus tended to be used in ways that all printed materials are. It is possible that the more familiar "school-like" format of the print allowed some teachers a comfortable entry point into the content of the Mimi package. Most of the teachers in our sample thought that the print materials were excellent ("If the children are able to prepare first with the books, they pick up a lot more [from the video]"). Interestingly, several teachers noted that the video caused the books to become valuable to the children. A few teachers, however, did not find the print materials useful or special ("The thing they [the children] liked least was the textbook because that's like everyday work").

In addition to making new information available for classes by causing a rearrangement of instructional exchange, the media caused the teachers to reexamine their lesson objectives by eliminating some traditional sources of feedback. All teachers were left to their own devices for evaluating the activities resulting from the use of the media.

One teacher hoped to develop a "process" test, but was disappointed that he was only able to devise a "fact" test. Some teachers managed to test vocabulary, recognizing that this was not the point of the Mimi. A couple of teachers, expressing some bewilderment about how to conduct assessment, gave assignments to the children and simply kept track of whether or not the work had been completed. One of these teachers had each child demonstrate to her that s/he was able successfully to play a computer game before the child was allowed to try another.

Television viewing and computer use, as well as the discussion and questioning that accompany them, do not easily lend themselves to formal assessment. "Testing is not in the spirit of the Mimi," said one teacher. Thus, while all the teachers found a way to integrate the media into their classes, the media demanded that they use new or more individually referenced means of assessing how the lessons suited their purposes. The different lessons engendered by the media may eventually help teachers work towards the goals of science and mathematics inquiry by encouraging a focus on process and problem solving.

The Effect of School Systems on the Adoption of New Technologies

The enthusiasm we witnessed among teachers is not enough to maintain the momentum for a project such as MASTTE. The adoption and diffusion of technological innovation in classrooms demands district-level as well as classroom-level planning (Loucks & Zacchei, 1983; Berman & McLaughlin, 1978). As each district attempted to adopt and incorporate new and integrated technology, constraints were revealed that operated upon both districts and individual teachers. Among the MASTTE sites, district-level planning was shaped, first, by the nature of the district's initial goals for participating in the project, then by the processes by which information was exchanged as the project was implemented, and finally, by the bases on which support and diffusion came to be structured in the district.

Goals for Participation in the Project

In order to help maintain the effectiveness of the new program in the districts, the MASTTE training program included opportunities for the participating school personnel to develop and clarify program plans and to devise strategies for organizing district-level support.

We found that the freedom to experiment afforded by the Mimi's multiple-entry design seemed to be the key to individual teachers' acceptance and use of integrated technologies: "I can use my strengths"; "It's good for myself and my background"; "I find the materials very useful and they suit my style of teaching, but my style is not everybody's style." However, as with any innovation, in order for individual experiences to affect practices across a district, the experimentation had to occur in districts which (1) could incorporate the project's goals into their own, and (2) had mechanisms for detecting and supporting professional growth among staff. In other words, the elements that sustained individual teachers as they changed their instructional practices resulted in district change when those elements became part of a district's plan for improving science and mathematics instruction.

The districts participating in the MASTTE project varied greatly in structure and, therefore, in how they addressed the problem of change. They represented a cross-section of New York area districts, including urban and suburban schools, districts with more or less extensive tax bases, school populations with a variety of ethnic backgrounds in different proportions, and districts of varying size:

District M is a large, central-city school district serving a mixed ethnic population, primarily hispanic and black. The participant schools varied in the extent to which they used educational technology. The personnel sent for training came from three levels of the system: classroom teachers from two sites, a school computer coordinator, and a district science coordinator who served 23 schools. District M was contacted about participation in the training program through the central office, as were the other districts. Yet, two teachers selected to attend were under the impression that they would be participating in a social studies program. Although District M did not articulate any districtwide plans for the MASTTE work, it did express a desire to expand the computer technology program in one of the participating schools.

District B, a large district in one of the boroughs, also serves a mixed ethnic population and has limited technology in its schools. Teachers from three schools and two district-level staff developers (Mathematics/Computer and ESL/Special Education) responsible for 28 schools were sent for training at Bank Street. Before the project began, the staff developers organized a school board meeting, which was attended by selected principals and included several PTA presentations about the project. The staff developers worked with the explicit goal of improving science, mathematics, and technology capabilities throughout the district.

South Bay is a small, working-class district in a suburb serving a mixed ethnic community. Only building-level personnel--teachers, science coordinators, and one computer coordinator--were sent to Bank Street for training. The district office, notably the superintendent's assistant, gave the project classes "carte blanche," that is, exemption from regular curriculum requirements and priority on equipment use. This district has a strong CAI program and an exemplary mathematics program. Its participation in the MASTTE project was part of a 3-year effort to upgrade district science programs.

Chesterfield is a small, upper-middle-class district in a wealthy suburb. A district mathematics facilitator and a science facilitator, both experienced with computers, attended the training week at Bank Street; teachers could not be spared from the classrooms. Technological resources are readily available in Chesterfield, and the district has an elaborate inservice program. All classes above the third grade have computers. The facilitators planned to organize their own inservice program on using the materials immediately after the Bank Street training week. This district was interested in exploring the integrative possibilities of the Mimi materials.

Results indicated that defining a goal for district participation in the project before training began was a necessary precondition for later diffusion of the Mimi. Surprisingly, the degree of a district's or school's technological advancement prior to the program had no relation to the extent of diffusion: Those who were determined to make the program work organized the needed equipment, while some sites with adequate technology did not expand the program.

In our sites, goals were critical because they legitimated and clarified implementation activities. Of the four participating districts, the three (District B, South Bay, and Chesterfield) that had clear ideas about why they wanted to introduce technology into their science and mathematics programs were able to develop districtwide implementation plans for the coming school year. These three districts organized their own inservice programs, which were slated to begin before school reopened in September. In District M, where the goal of the project had been and continued to be unfocused, despite training and the enthusiasm of the teachers, technological innovation was not diffused on a districtwide basis, and barely so within the schools.

Personnel Responsible for Implementation

Carrying out district goals involves training personnel who are regarded as key in the implementation process. Depending on whom the districts chose to send for training, initial support for using the new materials varied. At most sites, strong connections to the central office proved to be important for the effective implementation and diffusion of the project.

One of the city districts (District B) sent central office staff developers for training, with the result that for the first time in that district a link was established between classroom teachers and the central office. For the teachers, "there was a response [from the district]. A living being who said 'yes' [to experimentation] instead of 'why didn't you.'" Previously, the teachers had not even been aware that the district had staff developers, let alone ones who could offer positive support.

This responsiveness was somewhat unexpected since, according to our informants, the two city districts we worked with operate heavily on favoritism and have few resources for staff development. The staff developers have many schools to work with and little authority; the teachers are often at odds with the district about obtaining the things they need for their classrooms. Thus, it was encouraging that staff developers were able to forge links with the teachers in that context.

In the other city district of our sample (District M), the staff developers sent for training did not work together. One was the computer coordinator of his school; the other worked in schools throughout the district, but not out of the central office where decisions are made. The support that these staff developers were able to provide for teachers was limited or nonexistent since they themselves had so little support from and not much access to those responsible for allocating resources in the district. Consequently, acquisition of and access to equipment was difficult to organize at the beginning of the project.

One suburban district in our sample (Chesterfield), which sent district-level facilitators to training, has the resources to offer many courses and workshops at the district office. The teachers are encouraged to design inservice programs for their colleagues, and money is available for attending professional conferences. Teachers were given time off for district training in using the materials, staff developers conducted demonstration lessons and, generally, resources were made available to Mimi classes. In contrast, the other suburban district (South Bay) sent only building-level personnel for training. Although this district has resources, there are few interschool or centralized professional activities; individual teachers are encouraged to pursue professional development on their own. Each building in South Bay was provided with equipment at first, but then was left to organize its own materials and support for the Mimi work. This became relatively hard to do for those MASTTE teachers who worked alone in schools.

Thus, in Chesterfield and District B, implementation was overseen by trained staff developers who worked out of the central office. Their positions facilitated the teachers' getting the materials needed to undertake the project. In South Bay and District M, implementation proceeded independently in each school building involved in the project. South Bay building personnel, however, had a clear framework from the district in which to carry out their work and were assisted in implementing the program.

Feedback on Implementation

Responsibility for implementing the program, for assessing feedback from this experiment in technology adoption, and for delineating the next steps of implementation was distributed differently in the districts. Support for continued experimentation with the technology and for its diffusion also differed, depending on how heavily teachers' and staff developers' classroom experiences weighed and on the strength of the communication lines to decision makers.

All districts considered the informal, positive reactions of teachers and staff developers, and the increased amount of science activities in classrooms as evidence of the success of the Mimi. When the time came for deciding what direction the program would take in the coming year, two of the districts (South Bay and Chesterfield) made decisions about the diffusion of the materials at the central office level, with teacher input considered in varying degrees. Chesterfield had in place a planning and review structure for teachers and staff developers with which to formally assess the program. Although the two Chesterfield staff developers, in conjunction with the Assistant Superintendent of Instruction, drew up a diffusion plan before consulting the teachers. Teacher input, in the form of rating scales and discussion, was eventually used to verify and justify this plan.

In South Bay, decisions about expanding the use of the Mimi technology for the coming school year also were made centrally, but without systematic teacher or staff developer input. The opinions of project participants were heard at a group meeting by the Assistant Superintendent for Instruction but, based on their knowledge of the district, MASTTE participants doubted that their comments would carry weight in the district office. According to some of the South Bay people involved, making diffusion decisions without teacher input might work against the nature of the materials. The teachers felt that excluding them from decision making meant that budgetary or standard curriculum considerations were determining the use of the materials, thus overriding what the teachers had decided was relevant to their students. These feelings were expressed despite the fact that South Bay MASTTE participants were enlisted to conduct training of their colleagues for the coming year. The teachers felt that, by having the program and the use of particular materials mandated for the coming year, their professionalism had been challenged ("I feel some resignation about the whole thing").

Good communication lines to decision makers did not necessarily mean that central office control was exerted. In District B, for example, the staff developers used their knowledge of the system's workings to keep the program fluid for those teachers who were devising their own ways of using the materials. The District B staff developers, through private discussions and at meetings, helped district administrators and principals to understand that teachers needed support for exploring the best ways of utilizing the materials. In the meantime, the staff developers organized ways to provide meaningful feedback to administrators at a later date.

In District M, which neither had clear communication lines nor delineated central goals, interested teachers at each site pursued the project as best they could. In one school, the principal took active interest in the materials and sought to involve the science and computer teachers, as well as other classroom teachers, in the work. In the other school, the computer coordinator, who had attended training, introduced the materials to several new classes and planned some training for them. At both sites in District M, the teachers' positive experiences have kept the project alive in the absence of district support.

Teacher Support

Teachers are professionals who require short-term and long-term support, especially when being asked to change their professional practices. In our sample, district histories of administrative interest in teachers' needs, of professional treatment of teachers, and of decision making affected the implementation of the new technology. For example, one teacher in District M said:

> No one has mentioned to me or Ms. D: "How's it going?" or "Is there anything I can do to help?" There hasn't been one word--well, one: "Did you get the computer?" That was the extent of it. Not "if you're using it," not "how the children are reacting to it," "what materials did you get," nothing.

The teachers in this district struggled to maintain the momentum of their commitment.

We found that the informed involvement of administrators was essential for supporting teachers' feelings of professionalism: teachers felt that they could earn genuine recognition, were more likely to argue successfully for innovations, and could trust that their needs would be met in the future. Without such involvement, none of these teacher benefits was assured.

Some of the participants felt that the administrators in their districts did not really understand what the project was about. Teachers in two districts expressed resentment of what one teacher called "the white glove brigade"--administrators who were interested in publicity on technological developments in the district, but who made no effort to acquaint themselves with the actual work being done.

In the districts where administrators and parents were informed and involved in the adoption process, more activities and more extended activities were taken up by teachers during the first stages of implementation. The range of projects envisioned for the future was also greater in those districts.

There was one way in which district administrators could be helpful to teachers without being fully acquainted with the details of the project; namely, by providing them with material support. However, their own roles (e.g., obtaining resources, cutting "red tape") needed to be specified, and they did have to be generally familiar with the project goals. We found, too, that administrative and parental involvement was not necessarily related to an efficient process for obtaining equipment. Information short-cuts were benign only when there was a central support structure for teachers, such as a communications network. These support structures served as a guarantee that teachers' classroom equipment needs would be dealt with by someone who had access to a decision maker and could thus be an advocate. For the current group of teachers, a strong support mechanism was already in place in two of the districts; in a third, two district-level staff developers working together were able to construct a support system.

Diffusion

Although we found clear district goals to be important for undertaking innovation, there was some evidence that creating a central district implementation plan may have limited the range of innovations possible with the materials, and restricted the advantages afforded by the multiple-entry approach. By June of 1985, three months after the materials were introduced, the two suburban districts considered the pilot stage of the program to be over. The district coordinators knew what they wanted from the materials; that is, they decided which Mimi materials and activities were appropriate for particular grade levels and curriculum strands. In South Bay, for instance, it is now required that the Mimi be taught in fifth grade; in Chesterfield, a decision dictating the use of the Mimi will be made at the end of the 1986-87 school year. In both districts, teachers in grades not using the video episodes are still experimenting with the software modules, but within limits defined by the central office. In South Bay and Chesterfield, too, certain computer modules are to be used only in specific grades; video use in Chesterfield is restricted to one grade.

Personnel in both districts felt that the program was robust and efficient, and had confidence in their district's ability to deal with any problems that might arise, including procuring new equipment and training teachers in the use of technology.

The two city districts have maintained a "pilot" state of affairs concerning program implementation, one by default (District M) and the other deliberately (District B), in part because the staff developers supervising the program felt that three months was not enough time to fully evaluate its utility across grades and teachers. District B staff feel confident that the technology will eventually effect broad changes, but their approach is to involve the school and parent community through demonstration and education.

Conclusion

The science and mathematics materials comprising The Voyage of the Mimi attempt to address the pervasive problem of why these topics are often marked as irrelevant in a child's life. They do so by contexting science and mathematics concepts in a story and in integrated mixed-media activities for the classroom. Their effectiveness in achieving their aim needs to be understood in light of their impact on how teachers organize information systems for their students within the whole-school context. As we have seen in the few months of the program, the presence of the new technologies does not automatically prescribe the nature of the task for the teacher who is involved in motivating "problem-solving" activity on the part of the student.

Teachers were able to tolerate a wide range of conditions for working with The Voyage of the Mimi materials, despite the fact that many of their situations were far from ideal. The flexibility of the materials themselves, both in terms of their content and format, seemed to contribute to the flexibility with which they were used by the teachers in such a broad range of circumstances. While this made it necessary for staff developers to deal with each teacher's situation as an individual case, it may prove to be a more efficient outcome overall, since teachers felt they came to "own" the program; they could adapt lessons as they wished without feeling they were violating a prescribed sequence, skipping content, or under-utilizing the materials.

As the teachers become comfortable with the content of the materials, we anticipate that they will become more open-ended in their lesson arrangements (Guskey, 1986). As judged by the reports we received from the teachers, the multimedia materials, with suggestions for classroom use provided through training, inspired them to begin enrichment of their science instruction. Teachers in every district reported that the responses of their students to the materials were more powerful and consistently more positive than any they have seen. Not surprisingly, the increased attempts by teachers, following training, to use the materials for integrated science and mathematics activities revealed a set of teaching practices that are not always functional for subject integration. In many classrooms science is taught as a corpus of facts, and mathematics is a discrete subject dealt with from 10:00 to 10:45 ("Math class is a separate class"). Our observations suggest that the possibility of revising these practices is likely to depend less on verbalizations of alternative philosophies than on the mobilization of district resources that help teachers accommodate the developing interests of the children, the excitement of the classes, and their own increasing confidence.

In the classrooms we visited, the teachers' work seemed to be as much influenced by the technology as the technological applications were shaped by the teachers. Multiple routes into the materials for both inexperienced and experienced teachers meant that the materials could be utilized in some fashion by almost anyone. It is likely that the materials brought teachers into contact with factors that will encourage their further development as teachers of science and mathematics, namely: children's high interest; topics of interest to themselves; the legitimation of unanswered questions, which makes the teacher a learner too; and resources necessary for building a full program.

The school systems we studied significantly influenced and defined the project goals for the teacher. They delimited, to greater and lesser degrees, the boundaries of what was possible in individual classes by shaping the larger goals and human resources within which teachers explored the relatively uncharted territory of integrated technology. Whether or not schools were equipped with technological resources was of secondary relevance to what was possible (also see Shavelson, Winkler, Stasz, Feibel, Robyn, & Shaha, 1984). Rather, the school systems impinged on the adoption, diffusion, and richness of the program by dint of their organization of goals, communication, teacher support, and decision making. Individual experimentation by teachers in classrooms had different impact depending on the context of the wider system in which it occurred.

The content and concepts of science and mathematics are not easily accessible for either children or teachers, but we found the teachers very willing to change how children gain access to such information. According to observations made during three months of classroom visits following the MASTTE training program, adopting integrated technologies as tools for change as well as for learning can be a promising enterprise. We are continuing to investigate factors that seem to influence the adoption process, and to determine the ways in which training can address them systematically.

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