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ABSTRACT

Utilizing self-report data from 32 elementary and secondary teachers, this longitudinal, qualitative study examines the role shifts of both teachers and students as they adapted to teaching and learning in educational, technology-rich, Apple Classrooms of Tomorrow environments. At first, teachers in these instructionally innovative classrooms continued to rely on traditional teaching strategies despite radical physical changes brought about by the introduction of microcomputers, printers, laserdiscs, and other technological tools. However, over time, teaching methods changed from traditional lecture style to instruction dependent on student cooperative learning and peer teaching. Three major issues are addressed in this paper: (1) how and why teachers began to utilize student expertise; (2) how the roles of student experts were expanded as teachers recognized the benefits of peer interaction and collaboration; and (3) how changes at the classroom and institutional levels reinforced teachers' decisions to utilize student expertise. It is concluded that as teachers successfully attempt new classroom techniques, they see for themselves the value of educational strategies such as peer tutoring, and can re-evaluate their beliefs about teaching and learning. (27 references) (Author/DB)

Trading Places: When Teachers Utilize Student Expertise in Technology-Intensive Classrooms

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Prepared for a presentation at the 1991 meeting of the American Educational Research Association, Chicago.

Apple Classrooms of Tomorrow℠ (ACOT℠)
A Project of the Advanced Technology Group
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ABSTRACT

Utilizing self-report data from 32 elementary and secondary teachers, this longitudinal, qualitative study examines the role shifts of both teachers and students as they adapted to teaching and learning in technology-rich classrooms. At first, teachers in these innovative classrooms continued to rely on traditional teaching strategies despite radical physical changes brought about by the introduction of computers, printers, laserdiscs, and other technological tools. However, over time, instruction shifted from the traditional lecture-recitation-seatwork model to instruction heavily dependent on student collaboration and peer teaching. Three major issues addressed in this paper include: 1) how and why teachers began to utilize student expertise; 2) how the roles of student experts were expanded as teachers recognized the benefits of peer interaction and collaboration; and 3) how changes at the classroom and institutional levels reinforced teachers' decisions to utilize student expertise.

Trading Places: When Teachers Utilize Student Expertise in Technology-Intensive Classrooms

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Matthew's Log

January 28, 1987

> I lectured no more than ten minutes in science today. For the rest of the period the kids worked on a project. What effect will this have on their learning? (#5268/1, AT)[1]

May 10, 1989

> As the kids are presenting their HyperCard stacks, I'm able to allow them to assume the role of teacher and I assume the role of a student. . . . When the student runs into trouble, I can easily jump back into the teacher role. Sometimes we ask for others in the class to volunteer the information first. I kind of become the final person that can give information rather than the initial person in class. That's been a real neat role for me to follow here. (#8984/1, AT)

February 16, 1990

> I think the kids are gaining an extraordinary amount of . . . knowledge here of aquatic systems even though they're doing it on their own and it's not being fed to them by a teacher standing in front—the "sage on the stage" kind of concept. (#1230/2, AT)

The above quotes trace the development of a veteran high school science teacher involved in a project whose espoused goal is to change teaching and learning through the creation of technology-intensive classrooms. In the first quote, Matthew is concerned because he does not spend the entire class period in his traditional way—imparting knowledge to his students. In contrast, three years later, he is convinced that abandoning the "sage on the stage" model of teaching will lead to "extraordinary" learning.

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[1]The data notation system used throughout this paper indicates the source of the data (AT = audiotape data; WL = weekly reports sent via electronic mail; SL = telecommunications sent between sites), the episode's entry number in the database, and when the data were generated.

Along with approximately 30 other teachers throughout the country, Matthew is a teacher in the Apple Classrooms of Tomorrow[sm] (ACOT[sm]) project, which began in 1985. Students and teachers in ACOT have constant access to a variety of technological tools such as computers, printers, laserdiscs, camcorders, scanners, and a multitude of software programs.

ACOT's mission is formative: to explore, develop, and demonstrate powerful uses of technology in teaching and learning. As an agent of change, the program seeks to influence educational reform by implementing the following goals as an ongoing process:

- Build active, creative learning environments where children and teachers have immediate access to interactive technologies;
- Study how these environments affect teaching and learning;
- Document and share results with parents, educators, policymakers, and technology developers; and
- Use findings to recreate the vision.

One research project that has emerged from this collaborative effort looks at teachers' experiences in these innovative classrooms. This paper stems from that project and examines the role shifts that occurred for both teachers and students as they struggled to adopt and use the technology. This paper will describe aspects of instructional change across the classrooms in the project and will discuss the structural and programmatic shifts within the school environments that were necessary for change to occur. As was the case with Matthew, quoted above, instruction shifted over time from the traditional lecture-recitation-seatwork model to instruction heavily dependent on student collaboration and peer teaching.

Researchers investigating the impact of technology on education have examined the effect of computers on teachers' and students' roles in the classroom. Studies indicate that computer-oriented activities increase the level of peer interaction (Hawkins, Sheingold, Gearhart, and Berger, 1982), and lead to a more cooperative social structure in the classroom (Newman, 1990; Brown & Campione, in press; Scardamalia, Bereiter, McLean, Swallow, & Woodruff, 1989). The introduction of computers into the classroom changes the teachers' role as well, leading to decreases in teacher-directed activities and a shift from didactic approaches to a constructivist approach (Schofield & Verban, 1988).

The effects of peer interaction and student collaboration have been extensively investigated in traditional classroom settings. Formalized systems of peer tutoring and collaboration vary and include approaches that pair experienced students with relative

novices (Dedicott,1986); that combine relative novices who have roughly the same level of competence (Ames & Murray, 1982); or that divide children into heterogeneous teams of five or six who work both individually and together on a task (Slavin, 1983). Overall, researchers have found that these different types of peer learning situations enhance academic achievement in a variety of domains, such as writing (Reed, 1990); mathematical and spatial reasoning (Phelps & Damon, 1989); reading (Atherley, 1989); and foreign language (Chesterfield & Chesterfield, 1985). Peer learning has also been found to increase students' self-esteem and social status (Maheady & Sainato, 1985) as well as motivation and self-direction (Land, 1984).

This paper builds on the research discussed above but differs from it on several dimensions. First, unlike many studies investigating peer collaboration, this paper examines the teachers' perspectives and experiences rather than focusing on student outcomes. Second, since the data cover a five-year period, this paper takes a long-term view of teacher change. Finally, rather than examining the utilization of student expertise only in peer teaching, this paper discusses how students shared their expertise with a number of other individuals as well, including their teachers, school administrators, and family members.

SETTINGS

This qualitative study utilizes data from thirty-two elementary and secondary teachers in five schools located in four different states. The ACOT teachers contributing data to this study work in schools that represent the diverse populations and conditions found in contemporary public schooling. Each of these sites began with one classroom in the fall of 1986, adding classrooms, staff, and students in subsequent years. Table 1 summarizes the status of each site in the spring of 1990.

Site	Grades	Teachers	Students	Community/SES
1	1-4	8	180	Suburban/High
2	5-6	7	180	Rural/Middle
3	4-6	4	90	Inner-City/Low
4	4 & Sp. Ed.	4	80	Suburban-Urban/Low-Middle
5	9-12	9	120	Urban/Low-Middle

Table 1: Site Descriptors

In each of these settings, students and teachers have constant access to interactive technologies. The elementary classes are equipped with Apple IIe, IIGS, and Macintosh

computers. The high school is an all Macintosh installation. In addition to the computers, classrooms are equipped with printers, scanners, laserdisc and videotape players, modems, CD Rom drives, and hundreds of software titles.

The technology is used as a tool to support learning across the curriculum. No attempt is made to replace existing instructional technologies with computers. By design, the classrooms are true multimedia environments where students and teachers use textbooks, workbooks, manipulative math materials, white boards, crayons, paper, glue, overhead projectors, televisions, pianos, etc. as well as computers. The operating principle is to use the media that best supports the learning goal.

DATA COLLECTION AND METHODOLOGY

The sources of data for this study, covering from October 1985 through June 1990, include weekly reports sent via electronic mail; correspondence between sites; and bi-monthly audiotapes on which teachers reflected about their experiences. Although the study does not include observational data, hundreds of hours of systematic observations by independent researchers (e.g., Gearhart, Herman, Baker, Novak, and Whittaker, 1990; Phelan, 1989; Tierney, 1988) support the self-report data reported in this investigation.

Teacher Journals—Teachers record their personal observations of events in their classrooms and their reflections on those events on audiotape, producing on the average two 60 minute tapes per month. Instructions about content on the tapes are purposefully left vague, leaving teachers free to report what is most salient at the time to each of them.

Weekly Reports—The teaching staff at each site communicates weekly on major events and developments in a written summary that is electronically distributed among all project participants via Apple Computer's corporate networking system. Again, the content of the reports is left to the determination of the teachers at each site. Because these reports are publicly aired to everyone connected with the project, they tend to be more self-conscious than the personal, frequently introspective reports contained in the audiotape journals. Together, these two sources of data provide interesting contrasts on events at the sites.

The research team transcribed all written communications and summarized the audiotapes. To facilitate analysis, narratives were divided into episodes; each episode represents an event, with a beginning, middle, and end. Episodes were indexed for retrieval using a variety of categories and subcategories (e.g., participant, affective tone, context, general theme). The development of content categories followed the principles of "grounded theory" (Glaser & Strauss, 1967), "progressive focusing," (Hamilton, MacDonald, King, Jenkins, & Parlett, 1977), and "collapsing outlines" (Smith, 1978). The indexing system allows sorting and rapid retrieval of descriptive, qualitative data along a

number of dimensions for the construction of reports. Important themes and events emerge from the data in the "constant comparison" mode (Glaser & Strauss, 1967).

The data have been divided into two databases, which together have almost 20,000 episodes. Double Helix, a relational database, was used to manage and analyze the data. This software program allows data to be organized and displayed in a multitude of ways (e.g., by teacher, by school site, by dates, by thematic categories. For a thorough discussion of the methodology used for this study see Dwyer, Ringstaff, Sandholtz, Keirns, & Grant [1990]).

Since the project spans almost five years, some of the teachers represented in the database were not involved for the entire time. Thus, simply examining individual teachers' data in terms of chronological dates could be misleading. Understandably, instructional practices were often different for teachers joining the project at its inception (1985) than for teachers who began teaching in ACOT during the most recent year of data collection (1990) when the project was well underway. Also, each year of the project brought about changes in site organization, in the types of equipment that was available, or in project goals. Moreover, at some sites, teachers worked with the same students over several years, while at other locations teachers had to start each year with brand new students. Thus, rather than examining change within individual teachers over time, we viewed the data as a "collective consciousness," documenting shifts in teacher and student roles during the evolution of the project.

PERSPECTIVE

While reformers argue about the most efficient way to promote school change, one consistent finding is that, whatever its form, the process of educational change is typically slow and painstaking. Increasing attention is being paid to the idea that lasting change in the classroom must be accompanied by changes in teachers' beliefs about the purpose and nature of instruction, and that these belief systems are remarkably resistant to change.

Consistent with research on classroom innovation, teachers in Apple Classrooms of Tomorrow continued to rely on traditional teaching strategies during the early years of the project despite radical physical changes in their classrooms brought about by the introduction of computers, printers, laserdiscs, and other technological tools. By collecting data over an extended period of time, however, we began to see gradual shifts in teachers' beliefs about learning and teaching, and the consequences these changing beliefs had on classroom practice.

This progression can be viewed as an evolutionary process similar to other models of educational change (e.g., Berman & McLaughlin, 1976; Giacquinta, 1973; Gross &

Herriott, 1979). We have labeled the stages of instructional evolution in the ACOT classrooms: Entry, Adoption, Adaptation, Appropriation, and Invention (See Figure 1). In this model, text-based curriculum delivered in a lecture-recitation-seatwork mode is first strengthened through the use of technology and then gradually replaced by far more dynamic learning experiences for the students.

In the earliest stages of the project, ACOT teachers demonstrated little penchant for significant instructional change and in fact, were using their technological resources to replicate traditional instructional and learning activities. Even into the Adoption phase, students continued to receive steady diets of whole-group lecture and recitation and individualized seatwork. As teachers eventually reached the Appropriation phase—the point at which an individual comes to understand technology and use it effortlessly as a tool to accomplish real work—their roles began to shift noticeably and new instructional patterns emerged. Team teaching, interdisciplinary project-based instruction, and individually-paced instruction became more common at all of the sites.

This paper will provide an in-depth analysis of one aspect of instructional change—the willingness of teachers to relinquish their role as expert and utilize student knowledge. (For a more general discussion of changes in teachers' instructional beliefs, see Dwyer, Ringstaff & Sandholtz, 1991.) Specifically, this paper will examine:

- How and why teachers began to utilize student expertise in the classroom
- How the roles of student experts were expanded as teachers recognized the benefits of peer interaction and collaboration
- How changes at the classroom and institutional levels reinforced teachers' decisions to utilize student expertise

Finally, this paper will discuss the need for changes in teachers' and students' beliefs about their roles in the classroom. As teachers experimented with new instructional strategies, they confronted their previous beliefs about the role of teacher and student.

RESULTS

Utilizing Student Expertise in the Classroom

At the outset of the project, teachers, like their students, faced learning how to use a multitude of technology. As experienced teachers—knowledgeable about the curriculum,

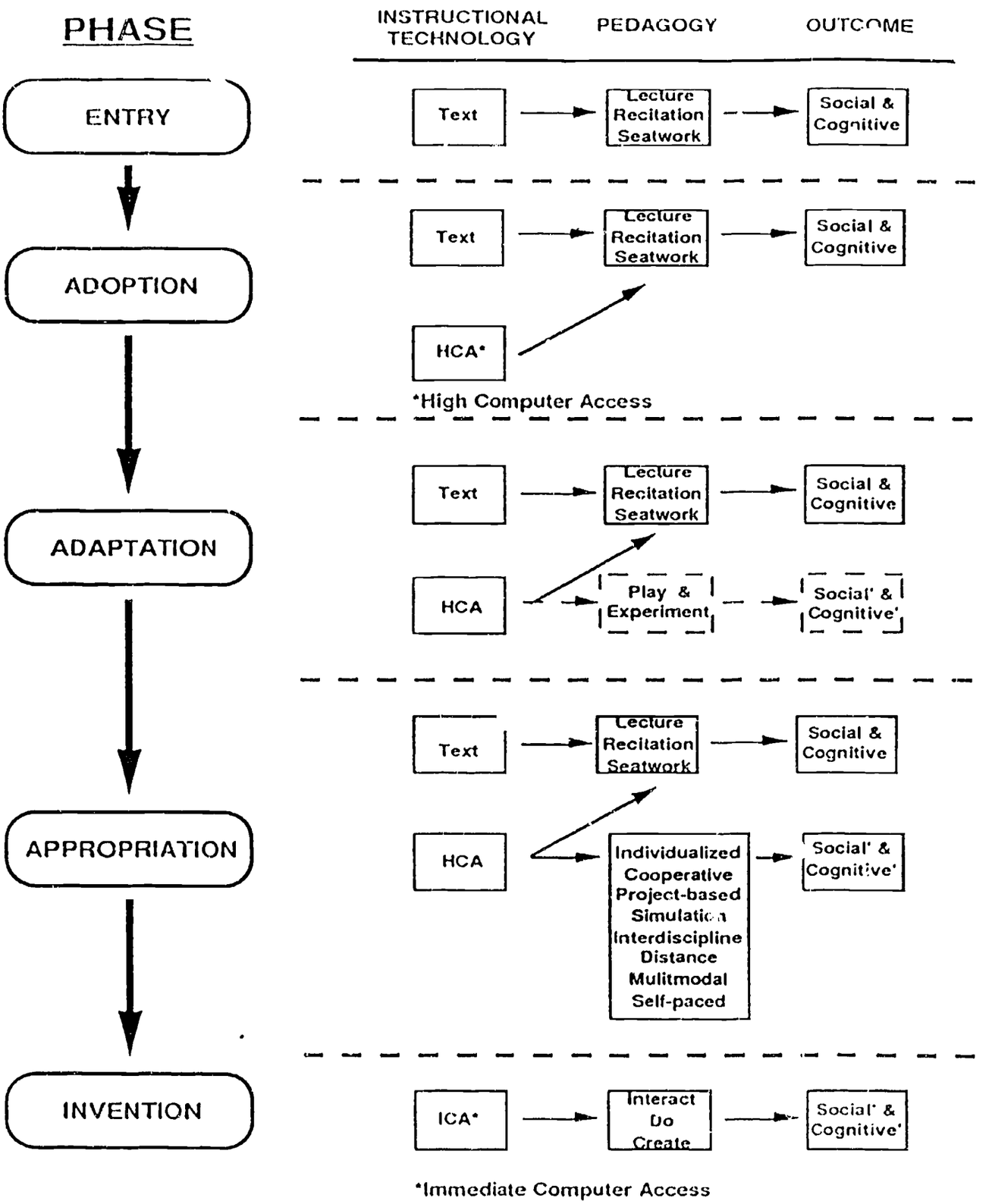

Figure 1: Instructional Evolution in Technology–Intensive Classrooms

classroom management, and principles of learning—some teachers felt discomfort about knowing little more than their students about the technology. In fact, before too long, some of their students had become experts in using particular computer applications, software, or hardware, and knew more than both their teachers and their peers.

At all of the sites, students began helping their peers and their teachers by providing technical assistance and tutoring on the use of the new technology. At first, students' role as "teacher" was sporadic, spontaneous, and unstructured. Rather than sitting quietly and waiting for their teacher to help them with the technology, students began to take the initiative and ask each other for assistance or volunteer information to one another. Even first graders offered to teach their friends how to boot a disk or maneuver a mouse. This sudden increase in peer interaction disturbed teachers who were accustomed to children raising their hands for permission to speak or leave their seats. Others, however, expressed delight about students' eagerness to share their knowledge:

> I was really pleased today with how the children finished their stories . . . . One child using Dazzle Draw didn't have enough room, and another child came over and showed him how to delete so he could have more room on his Dazzle Draw disk. I often wonder when the children discover and where they learn how to figure out the various pieces of software and the computer. I may have taught one—or none—and they have discovered on their own. (#10795/1, AT, 3-21-89)

During the early stages of the project, the students rather than the teachers usually initiated peer tutoring. Frequently, teachers observed that if they taught one or two students how to do something on the computer, the rest of the class would not need teacher-directed instruction because they learned informally from their peers. Eventually teachers began to capitalize more formally on students' technological expertise rather than relying on the classroom grapevine. For example, some teachers assigned various software packages to different students, asking each student to become an expert with one particular software title or tool. Other teachers asked students to take software home to evaluate, as in this instance featuring Carl, a 10th grader:

> Since Carl is already expert with PageMaker, he is studying Quark Express and coming up with a comparison on which product does what and which does he recommend if a school can only buy one. That should be valuable information for all of us. (#269/1, WL, 3-31-88)

Certain students began to play specialized roles in the classroom. For example, one teacher, Matthew, created his science tests with HyperCard. He quickly realized that Sam, one of his students, had a lot to teach him:

> Sam came in after class . . . and told me about all the things the kids could do to their test, if they really knew HyperCard, to enhance their grade . . . . He showed me how to beat the test. From him, I picked up one or two things that I knew how to do, but hadn't done. . . . It was a humbling experience. (#7220/1, AT, 11-30-88)

After this experience, Matthew regularly counted on Sam's expertise when creating tests on HyperCard. For Matthew, Sam provided the "acid test" of whether or not his Hypercard stack was well designed.

In the beginning of the project, teachers allowed their more "capable" students to serve formally as peer tutors, the assumption being that these high achievers would naturally excel in using the technology.

> One student got straight A's . . . . Frieda has plans to use the Mac to put together a newsletter to send home to parents. This particular student can then help teach the other kids to use the Mac to design the newsletter. (#4721/1, AT, 2-8-86)

Typically, teachers had their best students serve as peer tutors to save themselves time and to provide additional assistance to slower students.

> I am having the kids do a lot of work on the software manuals which I intend to use. They learn how to do HyperCard while saving me prep time (#244/1, SL, 3-9-88)

> Today I had one student who is really far ahead take a group of other students who had failed . . . and teach them. She did a good job and felt proud of herself, so I m going to try it more often. (#7164/1, AT, 10-14-88,)

Gradually, however, most teachers realized that even "slower" students had much to offer their peers:

> During book editing time, Shelly finished her book and just very naturally went over and started helping Tom. He had

> messed up part of his book. She just went over to help and did a nice job. She's very limited herself, but it is interesting how limited some of these kids are and yet how they collaborate with others on projects. They do it very naturally and do a nice job on it. (#5957/1, AT, 4-4-89)

While many teachers at first questioned the value of using students as teachers and wondered how it would affect learning, teachers soon realized that the benefits of this role shift went far beyond saving them time. Teachers saw "slow" students blossom, unpopular students gain peer approval, and unmotivated students stay in to work at recess.

> Joe is the talkative, annoying, misfit kind of kid which every teacher has had at some time. He loves the computer. He has not been popular with his peers, but he has caught on very quickly to Pascal. Other students are asking, "Can Joe come over and help me?" It is interesting to see how becoming an expert has influenced his class relationships. (#2567/1, AT, 1-29-88)

> I had a good breakthrough with one of my students today. . . . The kids were using LogoWriter to do a basic outline of the State of Tennessee. East and west boundaries of Tennessee are very irregular and the kids were having a lot of trouble doing it. Lee figured out how to do it with shape tables. . . . It was a novel solution to this problem. . . . Lee is not a "breakthrough" kind of kid ordinarily. There's something there that I've never been able to pull out before. . . .I was proud of him. (#6026/1, AT, 3-11-89)

Expanding the Role of Student Experts

As we noted, when ACOT began, most teachers had little knowledge of or experience with the technology. As it became apparent that students often knew more about the technology than their teachers and their peers, the teacher's traditional role as "expert" was undermined. Willing or not, teachers could not help notice the beneficial effects of student collaboration and interaction brought about by the introduction of technology to their classrooms. Eventually, teachers expanded their utilization of student experts along two dimensions. First, students began to share their expertise with people other than their peers. Second, teachers allowed students to teach one another subject matter content in addition to technological information.

A Changing Audience. In addition to providing assistance to their peers and their ACOT teachers, students shared their technical expertise with a variety of other people. At home, students often became the family's technical expert. For example, one

teacher commented that a girl in her class had to help her father make their home computer operational, "despite his continuous references to the manual" (#4999/1, AT, 11-3-87). Other students reportedly taught family members to use database programs or spreadsheets, or tutored siblings using the home computer. At one site, children were observed using the computers to help their parents learn to read!

At school, students instructed younger students, administrators, retired community members, non-ACOT teachers within the school, and even substitute teachers about the technology. One student, for example, showed the principal at her school how to use the electronic bulletin board. When a substitute teacher wanted to type a letter, several high school students taught her how to do word-processing. Some students spent time after school helping teachers who were not involved with the project learn about the technology:

> The art teacher came in to have a student show him Pixel Paint on the Mac. The typing teacher . . . wants to work with a student who can show her about word-processing. It is an excellent opportunity for both these teachers and the students. (#6793, AT, 1-13-89)

By the end of the second year of the project, even the school district valued the high school students' technological expertise. The district hired students as technical support people to help with setting up equipment and as teaching assistants in summer courses for district personnel. Teachers at the high school level began taking students' technological expertise for granted, forgetting that student-led classroom presentations on computer applications were not commonplace occurrences:

> What impressed our visitor the most was all the teachers coming into the room, taking the handouts and watching the [students'] presentations [on computer applications] and really learning something. We're so used to [student-led presentations] now, we just assume that a teacher who wants to learn would take advantage of these presentations, but [the visitor's] fresh viewpoint showed me that maybe this doesn't happen everywhere. (#7476/1, AT, 1-4-89)

Finally, both elementary and high school ACOT students discovered audiences for their skills beyond their classrooms, districts, and homes. One elementary group was invited several times over as many years to create technology classrooms in a shopping mall to help more community members understand technology. Three years in a row, another site took their classrooms to the state capitol, where they were featured at the annual state fair. Other students were asked to numerous state and national conferences and to an industry symposium to share their knowledge. High school students were hired by community firms

as technology consultants. One sixth grader was asked to devise a data system for his town's bank! And, perhaps most unique, a group of fourth graders and high school students accompanied by their teachers, were invited to testify before the Congressional Subcommittee on Space, Science, and Technology in Washington, D.C.

Students as Subject-matter Experts. Student experts' role was further augmented when teachers began to allow them to present subject matter content to the class. At first, this occurred infrequently, and often resulted from a teacher taking advantage of a "teachable moment" rather than being planned:

> We are covering the Civil War. . . . After we covered some of the battles, a couple of students came up and told me about a Civil War battle that happened around the high school area. I asked them if they would do some research on it and present it to the class . . . . I'm excited because I never knew that . . . . I've had students come up and tell me things before but I have not seen them go out and do research on it. This was from two students in the classroom who are not the best students. (#7890/1, AT, 2-2-89)

Eventually teachers at the high school level began planning entire units in which the students, rather than the teacher, presented the content to be learned.

> I'm getting ready to start my unit from last year when I was away from school and told the kids to figure out how to teach chapter six so they could teach it when I returned. This year I'll be here but I'm trying the same assignment . . . . I'll let them choose what method to use to present. (#7219/1, AT, 11-28-88)

Teachers typically found that this student-centered instructional approach took more time that the traditional format, but they felt that the time was well spent:

> Last week we did our 50's project . . . . I learned some things from students about animation and the Mac IIs. I really enjoyed this project because of the fact that I learned a lot and it really gave the students a chance to show their creativity. . . . We had planned two days for presentations and it took four days but the quality of the presentations was unbelievable. The presentations together taught the class about the 50's. It made my job a lot easier. (#8999/1, AT, 5-17-89)

In math and chemistry classes, teachers abandoned the traditional stand up and lecture mode of instruction. Instead, they asked students to coach one another.

> Students gathered in areas and were coached by their classmates wearing badges that designated problems that they were expert on. . . . I was a coach like the other students. (#657/2, AT, 12-12-89)

> I list the number of specific problems missed by students in the class on the chalkboard. Students who got the problem right and feel that they can explain the rationale for their answer place their names on the board under that problem. Students who missed the problem then have a resource person to ask questions if they can't understand why they missed the problem. . . . It is amazing how excited both classes are about this approach and it saves me from having to stand up in front and go over each problem as I did when I taught in the traditional program. (#254/2, AT, 12-6-89)

Classroom Strategies and Institutional Supports for Change

The process of change in ACOT classrooms involved more than introducing the technology and waiting for change to occur. Our experiences with ACOT suggest that two conditions aided successful reform. First, structural and programmatic shifts at both the classroom and the school level altered the context in which teachers worked. In some cases, these contextual shifts were relatively simple alterations that the teachers themselves initiated to enable them to take advantage more fully of student expertise. In other cases, the changes were more complex, and required the intervention and cooperation of ACOT staff as well as school and district administrators. Second, certain aspects of the ACOT project, such as data collection requirements and close working relationships between teachers and ACOT researchers, gave teachers the opportunity for reflection, promoting changes in teachers' personal beliefs about instruction.

Changes at the Classroom Level. As early as the second year of the project, teachers began to modify their teaching arrangements to take advantage more fully of student expertise. At one site, for example, teachers decided to combine their fifth and sixth graders for some activities to allow students the opportunity to teach each other. Once again, teachers reported seeing their lower-achieving students in a new light:

> What's neat about this is that the kids who don't normally shine are helping those older and sometimes more accomplished. The ideas trickle down through the kids—they show me what they're doing on the computer and we all learn. (#3438/1, AT, 9-16-88)

Other elementary teachers organized some of their lessons so that pairs of students could work together on the computers:

> When two kids are working on a computer, which is sometimes how I have them organized and working, the cliché "two heads are better than one" comes in. When they are working on a new piece of software, they help each other with it, they answer each other's questions, and they seem to figure things out together easier. (#7725/1, AT, 3-5-89)

At the high school site, teachers felt concern that new students would have difficulty keeping up with their older, more computer-literate peers. To provide the new students with the additional assistance they needed, they combined ninth- and tenth-grade students in study hall "to see what spontaneous interactions may occur" (#6793/1, AT, 1-15-88). Teachers also assigned students' seats with peer tutoring in mind:

> The ACOT teachers did a great job of arranging the seating chart in the sophomore class so that each new student is close to one or two students from last year that fit their personalities and will be the most helpful. The peer tutoring really takes the pressure off the teachers to try to do everything. (#9419/1, WL, 9-10-87)

Changes at the Institutional Level. At the same time that teachers were altering the structure of their classrooms, ACOT staff worked closely with school and district administrators to change the larger context in which ACOT teachers worked. Institutional supports, including technical training on the use of hardware and software, and release time for collaboration and team planning, became routine for ACOT teachers. The ACOT project also encouraged teachers to attend or present at professional conferences and regularly held workshops on instructional issues in response to teacher interest.

At each site, coordinators provided on-going technical and instructional support. Whenever possible, administrators permitted daily schedules to be flexible, allowing for peer observation and team teaching.

> The fact that [the other team member] and I can sit down, coordinate lessons, and get a chance to talk is a very important thing to what it is we are trying to do out here. I need to campaign that all teachers should have that time to coordinate with a team teacher and how important that is to the learning process. (#1143/1, AT, 11-9-89)

Teachers and coordinators also had access to a telecommunications network—linking participants, ACOT staff, researchers, as well as other educators. Teachers frequently used

the network to discuss instructional issues, provide emotional support, and share experiences with participants at other sites.

These forms of contextual support promoted change by decreasing teacher isolation. As teachers grappled with difficult instructional issues, they found it helpful to discuss their concerns with others in similar situations:

> James commented at our meeting that he is not comfortable at all with having the students work together. I felt uncomfortable with that last year, but ACOT has broken me away from that feeling, realizing that they can be very productive being instructional aides to each other. We pointed out to James that in our program if a student is having another student do their work for them, it's going to show on the test. Unlike the normal classroom, they can't just take their F and go on. (#7131/1, AT, 9-29-88)

Changes at the personal level. Opportunities for teacher reflection complemented these contextual changes and further promoted teacher change. The process of reflection helped teachers to see for themselves the benefits and drawbacks of different instructional approaches. Unlike many programs aimed at educational reform, ACOT provided built-in mechanisms that cultivated teacher reflection over the long haul. For example, as a data collection strategy, ACOT required teachers participating in the project to discuss their experiences on audiotapes several times a month. Although some teachers grumbled about the time necessary to comply with this requirement, many recognized the value of the experience:

> These tape requirements that you have given us were the pits at first. Now I am really into them as a means of mental release. . . . Anyhow, I'll stop beating around the bush. My tape recorder is broken. I now have nothing to talk into every day and I am feeling very panicky. Is there any way you could bring a new tape recorder to the MECC conference? I would really appreciate it. (#637/1, SL, 11-10-87)

At each site, the coordinator and teachers also generated weekly reports to keep ACOT staff and participants at other sites up-to-date on major events and developments in ACOT classrooms. The process of completing these reports, which were telecommunicated to other sites, gave teachers further opportunity to reflect upon their teaching.

Another research component of ACOT involved having individual teachers working closely with university-based investigators on issues such as student empowerment, multimedia instruction, and mathematics software. Once again, teachers sometimes

complained about the time they had to commit to these activities, but they also acknowledged that working closely with researchers had important benefits:

> This experiment with Cornell is really forcing me to think through my thought processes about what I am doing and questions I am asking. It is really good and healthy for me to experience these challenges. I feel I am growing and learning more about myself, and becoming more aware of what is happening in the classroom. (#137/2, AT, 9-11-89)

Not only did working closely with researchers increase the opportunity for teachers to confront their own beliefs about teaching and learning, but also validated their efforts to change:

> [Working with researchers] lets me know that I am not doing such a bad job, that I do come up with some good questions, and that I am becoming more secure about myself as I become more experienced [at using a new teaching approach]. (#137/2, AT, 9-11-89)

Similarly, periodic visitors to the classroom provided an important audience for ACOT teachers. The visitors served as a source of valuable feedback which increased the teachers' reflection on their practices and reinforced their experimentation with new methods. Being constantly observed by colleagues, particularly those from other schools, reemphasized the importance and value of their innovative strategies. Moreover, the changes teachers made in their instructional techniques were pervasive enough to be noted over time, rather than being temporary alterations meant to impress occasional visitors.

DISCUSSION

Although traditional components of instruction such as whole-group instruction, recitation, and individual seatwork still exist in ACOT classrooms, data collected over the five years of the ACOT project indicate that ACOT teachers have redefined their roles. Student-centered instruction, team teaching, interdisciplinary project-based instruction, and individually-paced instruction have become more and more common at all of the sites.

Undoubtedly, these shifts in teachers' instructional patterns cannot be attributed solely to the introduction of technology to classrooms. Rather, the addition of technology served as a catalyst for change by setting the stage for teachers to learn that they do not always have to play the traditional role of "dispensers of knowledge." Involved in innovative classrooms, many teachers felt at greater liberty to experiment with new

instructional techniques. Technology itself did not create major changes in instruction, but instead served as a symbol of change, inviting teachers to re-examine their beliefs about teaching and learning.

Teachers in ACOT classrooms moved toward child-centered rather than curriculum-centered instruction; toward collaborative rather than individual tasks; toward active rather than passive learning. Each of these dimensions brought deeply held beliefs about instruction into conflict with what teachers witnessed in their classrooms. The conflict never transformed those beliefs outright; the process seemed more gradual: an erosion of the old, an accretion of the new. During the process of change, teachers continually questioned their beliefs and actions:

> As you work into using the computer in the classroom, you start questioning everything you have done in the past, and wonder how you can adapt it to the computer. Then, you start questioning the whole concept of what you originally did. (#5857/1, AT, 12-8-88)

> It's been a real hectic week. I got myself into one of these ruts where I was trying to get things done by such and such a time and I didn't think through what I really should have done. It dawned on me. [The student] really should have presented her own [Hypercard stack on viruses] rather than me presenting [her] material. So, I apologized to [her] today and told the rest of the class to be prepared for when their chapter came up, that they would be ready to talk about it. (#8974/1, AT, 4-27-89)

As teachers changed their views about teaching and learning, students also had to adjust their thinking about their role in the classroom. New students, for example, were not accustomed to being able to ask their peers for assistance, since, in many classrooms, such interaction would be discouraged or even considered tantamount to cheating:

> We teachers and the experienced students have been trying to give the new students lots of help and support. Being able to ask classmates for help is strange to the newcomers. (#2284/1, AT, 9-2-88)

After years of viewing the teacher as the classroom expert, some students also found it difficult to think of their peers as valuable sources of information:

> The 10th and 11th graders are used to using each other as resources, asking questions and giving help, but it is new to the ninth graders. It was really neat today to see them begin to work with each other, realizing that the teachers aren't

> their only source of help and support. (#2302/1, AT, 9-14-88)

Eventually, however, students' beliefs about instruction shifted, and as they moved into the role of teacher, they started to see the benefits of particular instructional strategies. For example, in evaluating their peers' class presentations, students started to prefer methods requiring active involvement rather than passive forms of instruction such as the traditional lecture.

> Many of the presentations were quite delightful. . . [but] most of them taught the way I probably teach now—too much talking. I asked the students to reflect on how effective the groups were, and the students said "too much talking" when the students were just lecturing to the group. More and more we see that the active involvement is what grabs them. That's when they learn something. (#7096/1, AT, 2-1-89)

As students gained more and more responsibility for their learning, they developed a greater sense of ownership in the process of instruction. They began to request additional opportunities to share with each other, and when teachers reverted to old instructional patterns, students quickly complained:

> The students love to share what they're learning on LogoWriter. We decided to have a sharing meeting once a week. . . . They really feel that the meeting is theirs and they're anxious to share. I tried to teach some things during one meeting and they let me know that they were unhappy about me taking up their sharing time. (#4284/1, AT, 2-26-88)

In summary, over the years we have watched ACOT teachers first succumb to the sheer necessity of getting help with the technology—even from their students. First reluctant and uncertain, teachers gradually gained confidence in the benefits of student collaboration. Evidence for their change in thinking includes the increasing frequency of collaborative opportunities for students, the move toward allowing students to serve as subject-matter experts, and the expanded audiences of these tutors from their classroom neighbors to teachers, parents, siblings, and communities. The benefits of utilizing cadres of student experts include: a) the freeing of teachers from repetitious delivery of basic technology and learning skills; b) instruction occurring on more personal levels as students help each other, one on one; c) positive changes in students' academic performance; d) positive changes in students' senses of self-efficacy; and perhaps most important in the long run, e) changes in the perceptions of teachers, administrators, and parents about the capacities and talents of children. Most rewarding are stories about children who have been

perceived as slow or reluctant learners, blossoming as youngsters with promise when given an alternate avenue for the expression of their knowledge.

IMPLICATIONS

In countless classrooms across this country, millions of teachers and students engage in activities that are familiar to all of us: lecture, recitation, and seatwork, which, despite decades of educational reform, continue to predominate instructional practice. Instructional variations, of course, do exist—cooperative learning, discovery learning, mastery learning, *ad infinitum*—but educational movements aimed at creating fundamental change in schools have, for the most part, seen little success.

Despite the discouraging track record of many reform movements, the ACOT experience illustrates that significant change *is* possible, but requires time, patience, and a high level of support. The introduction of technology to classrooms will not radically change teaching; instead, technology, as a symbol of change, provides teachers with a license for experimentation. As teachers successfully attempt new ways of instruction, they see for themselves the value of strategies such as peer tutoring and collaboration, and can then begin to re-evaluate their beliefs about learning and teaching. Only when teachers' underlying beliefs about instruction are altered will serious reform efforts be successful.

Results of this study also suggest that, as teachers move toward models of teaching that include high levels of peer collaboration, traditional forms of assessment may not be adequate. When students are allowed to openly share information with one another—a common feature of technology-rich classrooms—customary forms of measuring student knowledge and achievement may not suffice. In the following quote, a teacher unfamiliar with computers is working closely with an ACOT teacher in a physics lab. The ACOT students are helping their non-ACOT peers learn how to use Excel spreadsheets for data collection. The quote illustrates the dilemma facing teachers who are learning how to use technology and trying to adapt to higher levels of peer interaction:

> We've got a veteran teacher over there who's got 27 or 28 years of teaching experience and has never used computers in his classroom. He said, "I'm a little afraid of this whole thing." I said, "Well, the kids know what's going on." He said, "Yeah, that's the scary part—they know what's going on and I'm not sure I know how to evaluate it." (#1180/2, AT, 12-11-89)

A study investigating assessment in ACOT's technology-intensive classrooms (Gearhart, et al., 1990) suggests that students who are the most successful at peer tutoring

or at demonstrating technological expertise to others typically do not have the highest grade-point averages in their classrooms. Although teachers' pride in these student experts is evident in weekly links and audiotapes—and in the verbal support they provide to these students—teachers do not know how to translate students' teaching skills into a grade on a standard report card. Clearly, the development and dissemination of alternative assessment techniques is necessary so that these teachers can more accurately measure and describe their students' progress.

Also, this study further demonstrates the power of the "apprenticeship of observation" (Lortie, 1975). As students were teaching each other how to use the technology—a skill with which they had little experience in schools—hands-on instruction was the norm. However, when students began to deliver content information to one another, they typically taught as they had been taught. In an earlier quote, one teacher succinctly captures the problem with many student presentations: "Most of [the students] taught the way I probably teach now—too much talking" (#7096/1, AT, 2-1-89). To be more effective, student experts will have to be provided with instructional techniques that go beyond the traditional lecture-recitation-seatwork model.

Just as teachers were at first reluctant to draw upon the knowledge and skills of their students, so too are districts hesitant to recognize local experts—their teachers—as resources. Instead of using outside consultants to provide inservice training, districts should consider the benefits of utilizing their teachers' expertise. Besides saving the district time and money, staff development conducted by insiders can lend credibility to an innovation when the teachers who are being trained realize that the innovation is being used in a setting similar to that in which they are working.

Finally, our experiences with ACOT highlight two important issues related to peer tutoring and collaboration. When considering implementing some type of peer instruction in the classroom, teachers often think that their more advanced students will best serve as experts. This study illustrates numerous benefits to allowing lower-achieving students to play the role of expert. Not only will teachers, peers, and family members see these students in a different light, but the experience will often enhance the student expert's self-esteem. Second, students should not be limited to sharing their expertise only with their peers. As this study demonstrates, teachers, administrators, parents, and siblings can all learn from student experts.

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