Different kinds of classrooms and teaching approaches led to different kinds of student collaborations.

revision seemed to match Cochran-Smith (1991) — students corrected errors and added to the end of texts, but were less likely to move text around or change parts of sentences. Ms. Boston said it was "important that children write every day," and student work on journals and in writing their own stories was something that went on every day in her classroom. Most of the computer use involved children using painting or writing programs at individual computers, with various kinds of helping and sharing of information, both about content and about how to use the computer.

One of the original goals of the design of *StoryShow* was to build a composing tool that could be easily used by two students working together on the same project. Choosing projects and students was left to the teachers involved in this study, and one result was that different kinds of classrooms and teaching approaches led to different kinds of collaborations among students using *StoryShow*.

In Ms. Boston's class, all student editing happened during input. Software features allowing movement of slides and slide elements were not used at all by this group.

Despite limited experience using StoryShow, students had little trouble importing images and sounds.

Providing easy to use editing tools didn't encourage editing. The writing tasks students do need to require editing.

In Ms. Boston's class, all student editing was at the point of input. Features in the software designed to enable the movement of slides and slide elements were not used at all by this group. These features occupied large amounts of development time, and were included to make possible the sorts of higher-level editing paralleled by the copy, cut, and paste features of word processors. Perhaps not surprisingly, although this group of students has highly developed skills for using the computer, their editing/revision strategies tended to be surface level only. Even in writing with word processors they often made spelling corrections or added text to existing paragraphs or corrected sentences as they wrote them, but didn't move things around, or attempt to completely rewrite existing sentences. Ms. Boston said that students did do more revision of their work with the computer, but most of that activity centered around correcting spelling errors. As a result, it is not surprising that the editing features built in to *StoryShow* were not used. Again, classroom practice was the primary factor in how the technology was actually used. A useful question to consider is how existing practice might be successfully combined with technology to encourage particular types of writing and composing activities that are seen as desirable, such as higher-level editing and revision. Attempting to encourage editing by providing tools to facilitate it is inadequate — the tasks students engage in need to require that editing be a desirable part of the process.

While existing classroom activities did not encourage much editing or revision of story elements, the classroom structure did seem to support the sort of independent, student-centered group work that the *StoryShow* activity permits, and students' experience with computers as well as working with each other seemed to facilitate the group production of text.

Students' experience with computers as well as working with each other seemed to facilitate the group production of text.

They were accustomed to sharing tasks in large group productions such as choral readings, and they had experience writing and sharing stories with the rest of the class. In the other two classrooms, students worked only in pairs, and where the pairs were accustomed to working together things went relatively smoothly, but when they were unfamiliar with each other's styles, the process was not as smooth. A larger group makes this kind of individual conflict less likely, although it also complicates the distribution of power in the composing process, as this report shows.

Knowing their work would be shown to an audience played a role in how students structured their composition.

Overall, the presence of an integrated reading-writing program where students were accustomed to writing about things they read and sharing that with other students, as well as working together, seemed to facilitate the use of *StoryShow* in interesting ways. This activity was seen as valuable by the students involved, in part because they were doing something that other students were not, but also because their work was presented to the whole class with the lights out. Knowing that an audience existed for their composition seems to have played a role both in the structure of their composition — an introductory slide announcing the content and a final slide identifying each author — as well as in their emphasis on getting each sound right and making sure it was clearly audible. Their final slide took six tries before the sound was deemed acceptable by the group.

Language is the medium through which students shared power and content. Technology control was only a secondary feature of the collaborative process.

While *StoryShow* was designed for two children working together, it really doesn't provide any special tools to enhance the collaboration. Language, as Schrage (1990) noted, is ultimately the primary tool of collaboration. Certainly language is the medium through which students in this study shared power and content. Control of the technology was only a secondary feature of the collaborative process. Language was used to direct the content and the operation of the software, to accept or reject images and sounds that became part of the composition, and to plan each slide as it was constructed. While the software can be seen as the focus of the process, language was really the tool of collaboration.

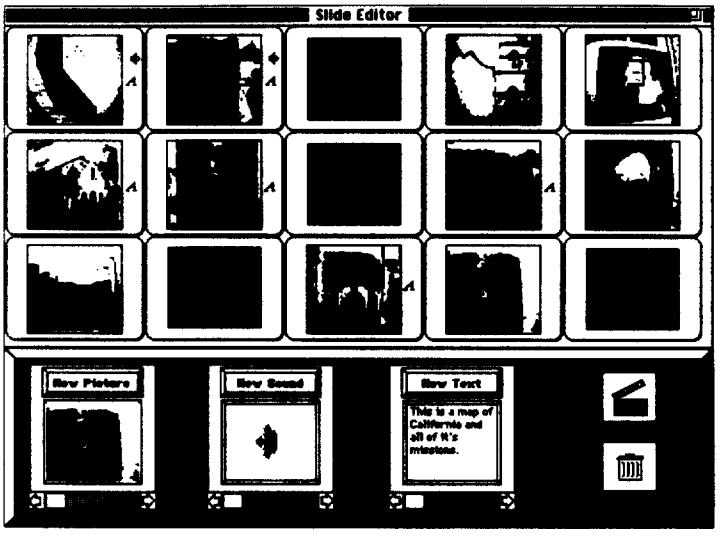
Although students had very limited experience using StoryShow, they manage the process of importing sounds and images with little difficulty.

Although students had only limited experience using the software, they were able to manage the process of importing images from the video camera and record sounds without much difficulty. To a large extent, the software did not get in the way of their activity. However, there were several instances where moving from one "mode" to another was confusing. For example, they employed a consistently linear process when constructing their composition — they moved from slide #1 through to slide #9 one by one, first capturing an image and then adding a sound to the image. No text was used for any slides. Breakdowns, defined as instances where production or manipulation of an element was interrupted by a problem with the software, seemed to occur when students moved from image capture to sound recording, a procedure which involved clicking on specific buttons to close the video camera and return to the slide editing area. On several occasions students opened a new window to capture an image on one monitor, then moved back to the main slide window without closing the capture window, causing the software to function incorrectly. In addition, this movement necessitated the dragging of a screen window from one monitor to another each time. This process is initially very disorienting, as it involves moving an object between two screens which are physically separate. When the object is dragged to the right edge of one screen, it then appears on the left edge of the second screen, which is several inches away from the first screen. Use of the second screen was necessary to allow videotaping of screen interactions as well as the use of the video capture for images. A more elegant solution might be to incorporate the image capture directly into each individual slide to avoid the mode switching and perhaps facilitating faster construction of the compositions.

Because these children did no editing other than to reject particular images or sounds and retake or re–record them, the switching from capture to edit mode served no purpose other than to confuse them.

Because these children did no editing except for rejecting certain images or sounds and re-taking or re-recording them, the software feature allowing users to switch between capturing and editing mode confused the students.

A second feature of the software which was not used at all again relates to the modality of the slide images. An initial screen shows 15 slides in small form — images are approximately 1/20 original size, and text and sounds appear only as icons on individual slides.



The software shows 15 slides in small form. Images are 1/20th original size and text and sounds appear only as icons on individual slides. Children never 'clicked' on these slides to view or hear the slide because editing decisions were made at the point of import.

To view or hear the slide, one can double–click the mouse on the image or part of the slide. In this study, that operation was not performed even once. Editing decisions were made at the point of import — when an image was grabbed using the camera and video capture software/hardware, it was either accepted or rejected. The same procedure was followed for sounds.

Again, redesign of the software could make this process easier by eliminating the use of the small slides and filling each screen with the original size image along with the image capture controls, sound controls and text area. Image, not text, predominates in the design of the software, so a redesign that incorporates text more prominently might increase the use of written language by younger children.

If the software were re-designed so small slides were replaced by large images with image, sound and text controls, the editing process may become easier.

With most software, files are saved with names given by the user of the software. Instead, *StoryShow* generates names for each image, sound, and text, and each of these objects are kept as small icons at the bottom of the screen to be added to a specific slide by dragging the image up to the slide. For images and text, this works well, as the icon usually provides a visible clue as to what the entire image or text is — a shrunken picture or the first few words of the text. For sounds, the visual representation offers no clue as to the content, making browsing through sounds a tedious process of listening to each one entirely. What is needed is a way to sample the first two or three seconds of the sound. Lacking this, the size of the sound is represented by icons which show more waves coming out of a speaker to indicate longer sounds. (See figure below.)

shorter sound

longer sound

The software was designed for images. A re-design that incorporates text more prominently might increase the children's use of written language.

This feature, and others with a "collect-browse-assemble" orientation tended to be ignored by students. Instead, all composing was done one slide at a time. A picture was captured and saved, followed by a sound. This eliminated the need to browse through images and sounds, and argues for a redesign of the software to better fit the composition style of the students.

As a collaborative tool, *StoryShow* functions reasonably well in an environment where collaboration is already common. The presence of multiple input devices, and multiple roles for participants, allow groups of up to five or six children to work together on a composition. What is clear is that the collaboration is tied to the social setting in which the software is used and is not an outgrowth of any particular design features aimed at encouraging collaboration.

The iconic delineation on stored sounds offered no clue about content, making sound browsing tedious. An ability to sample initial seconds of sounds might encourage browsing.

In a first grade classroom where students were less accustomed to working independently and were paired as a result of completing an assignment first rather than by choice, the software was used one at a time, with each child creating a single slide as the other watched or assisted with reading of the text, or correcting spelling errors on the screen. This kind of collaboration is similar to that among the first graders using word processing software described by Heap (1989). When one student has final control over content, whether for the text of a story or for the image, sound, and text in an individual slide, it is not clear that another student assisting with input or corrections is really collaborating as a coauthor. To call such interactions collaboration may honor the work of the assistant too highly. Collaboration at the level of content seems a different matter than sharing the task of typing. In Heap's study and others like it, collaboration is part of the social structure of the classroom that permits it to happen, but it often occurs because there is a limited amount of technology, often one computer per classroom. Such a set-up almost requires that children work together if enough students are to master the computer, on whatever software is available. Designing software specifically for collaborative work will require attention both to the writing practices of classrooms as well as an understanding of the kinds of social relationships that exist among students and teachers in classrooms.

Features enabling students to collect, browse and assemble tended to be ignored by students. All composing was done one slide at a time.

This report was part of a larger study of the introduction of multimedia software designed for use by pairs of children. In each of the three classrooms where the study was conducted, students used *StoryShow* to construct presentations rather than stories, and in Ms. Boston's classroom, students worked in groups of four to six rather than in pairs. A number of factors contributed to how the software ultimately was used, including how it was interpreted by individual teachers, how well it fit into the ongoing reading and writing activities of the classroom, and how students chose to use it. While the software design can be seen as successful from a technical perspective because students in first, second, and fourth grades were all able to use it with very limited instruction, a closer look at actual use suggests that technical mastery is not closely tied to using software in ways that are interesting or involve children in reading and writing in new ways.

The presence of advanced technology for creating multimedia compositions requires curriculum support that gives students a sense of how to combine different media effectively. Given the extremely limited presence of multimedia composing tools in schools, it is unlikely to expect teachers to easily integrate such tools into classrooms which still tend to focus on paper as the primary medium of communication, whether as part of writing, drawing, or word–processing activities.

Software designed for particular audiences and tasks will be used in ways that are supported by the context rather than by the software. In this case, what mattered most was not

While software design can be seen as successful from a technical perspective because first, second and fourth graders used it after limited instruction, technical mastery isn't closely tied to using software in ways that are interesting or involve children in reading and writing in new ways.

the presence of expensive computer hardware and the software to allow students to create multimedia compositions, but a classroom environment which supported the kinds of independent and collaborative activities that the software made possible. Without a supportive environment, the software was little more than an object of fascination for bringing together a variety of new technologies, and permitting students to replicate their work in a new medium.

What matters most isn't the amount of technology available, but a learning environment that supports independent and collaborative activities.

As Mehan (1989), Cochran-Smith (1991), Hawkins (1987) and Genishi (1988) have shown, technology is not always the key element when considering how a particular hardware or software innovation actually gets used by students. The classroom is a social environment with a variety of relationships, norms, and practices which exist prior to the introduction of a new technology. How a new technology is used owes as much to the ongoing activities of the classroom as it does to any particular features of the technology.

How a new technology is used owes as much to the on-going activities of the classroom as it does to any particular technology feature.

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Note: *StoryShow*, the multimedia software used in this study, was developed at Apple Computer, Inc. by the author, Brian Reilly, based on an original concept by David C. Dwyer Ph.D., project manager and principal scientist of Apple Classrooms of Tomorrow.

Note: All names in this report are pseudonyms.

This report is a summary of a paper presented to the American Education Research Association in San Francisco in 1992. Editors were Jenny Abbe and Mary A. C. Fallon.

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APPLE CLASSROOMS OF TOMORROW

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

Authors
Cathy Ringstaff Ph.D.
Apple Computer, Inc.
Judy Haymore Sandholtz Ph.D.
University of California, Riverside
David C. Dwyer Ph.D.
Apple Computer, Inc.

ACOT Report #15

Apple Computer, Inc.
20525 Mariani Avenue
Cupertino, CA 95014

Researc

The Study

This study examines the role shifts of teachers and students as they adapt to technology-rich classrooms.

Begun in 1985, Apple Classrooms of Tomorrow (ACOT)[SM] is a research and development collaboration among public schools, universities, research agencies and Apple Computer, Inc. ACOT explores, develops and demonstrates the powerful uses of technologies in teaching and learning. In all ACOT endeavors, instruction and assessment are as integral to learning as technology.

Supporting a constructivist approach to learning, technology is used as knowledge-building tools. As students collaborate, create media-rich compositions and use simulations and models, researchers investigate four aspects of learning: tasks, interactions, situations and tools. The research is formative. The findings guide ACOT staff and teachers as they refine their approach to learning, teaching and professional development. ACOT teachers and students often use the most advanced technologies available, including experimental technologies, to help us envision the future and improve the educational process.

ACOT views technology as a necessary and catalytic part of the effort required to fundamental restructure America's education system. We hope that by sharing our results with parents, educators, policy makers, and technology developers the lessons of ACOT will contribute to the advancement of educational reform.

This is an in-depth analysis of the willingness of teachers to relinquish their role as expert and utilize student knowledge. It examines how and why teachers use student experts, how their roles expanded, how peers benefitted, and how classroom and institutional changes reinforced the use of student experts.

Utilizing self-report data from 32 elementary and secondary teachers, this 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. Over time, instruction shifted from the traditional lecture-recitation-seatwork model to instruction heavily dependent on student collaboration and peer teaching.

We observed a shift from the traditional lecture-recitation-seatwork model to instruction heavily dependent on student collaboration and peer teaching. Researchers have found that these peer learning situations enhance academic achievement in a variety of domains.

This paper provides an in-depth analysis of one aspect of instructional change — the willingness of teachers to relinquish their role as expert and utilize student knowledge. It investigates how and why teachers began to utilize student expertise, how the roles of student experts were expanded as teachers recognized the benefits of peer interaction and collaboration, and how changes at the classroom and institutional levels reinforced teachers' decisions to utilize student expertise.

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]

[1] The data notation system used throughout this paper indicates the source of the data (AT = audio tape 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.

Our study differs from many investigations because it focuses on the teachers' experiences and perspectives, not on student outcomes.

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)*

The 32 elementary and high school ACOT teachers in this study worked in schools representing the diverse populations and conditions found in contemporary public schooling.

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 during his first few years as part of the Apple Classrooms of Tomorrow project. In the first quote, the teacher is concerned that he is not spending the entire class period in his traditional way—imparting knowledge to his students. Three years later, he is convinced that abandoning the "sage on the stage" model of teaching would lead to "extraordinary" learning.

This report examines the role shifts that occurred for both teachers and students in ACOT classsrooms as they struggled to adopt technology, and the structural and programmatic shifts necessary within the school environments for change to occur. As in Matthew's case, we observed a shift in instruction over time from the traditional lecture-recitation-seatwork model to instruction heavily dependent on student collaboration and peer teaching.

Technology is used as a tool to support learning across the curriculum. No attempt was made to replace existing instructional technologies with computers.

Previous studies examining the effect of computers on teachers' and students' roles in the classroom indicate that computer-oriented activities increase the level of peer interaction (Hawkins, Sheingold, Gearhart & Berger, 1982), and lead to a more cooperative social structure in the classroom (Brown & Campione, in press; Newman, 1990; 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).

From October 1985 to June 1990, teachers wrote weekly reports and twice monthly created an audio record of reflections about their practice.

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 the pairing of experienced students with relative novices (Dedicott, 1986); combining relative novices who have roughly the same level of competence (Ames & Murray, 1982); or creating teams of five or six students with varying abilities who work both individually and together on a task (Slavin, 1983). Overall, researchers have found that these 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).

Our study differs from many investigations of peer collaboration by focussing on teachers' perspectives and experiences, rather than on student outcomes, and by discussing how students went beyond peer teaching to share their expertise with teachers, school administrators, and family members. Also, since the data cover a five year period, this paper takes a long term view of teacher change.

Because not all teachers were involved all five years of the study, we viewed data collectively, documenting overall shifts in teachers' and students' roles during the project's evolution.

This qualitative study utilized data from 32 elementary and secondary teachers in five schools located in four different states. The ACOT teachers contributing data to this study worked in schools representing the diverse populations and conditions found in contemporary public schooling. Each of these sites began with one ACOT classroom in the fall of 1986, adding more classrooms, staff, and students in subsequent years.

In each of these settings, students and teachers had constant access to interactive technologies. The elementary classes were equipped with Apple IIe, IIGS, and Macintosh® computers. The high school is an all Macintosh installation. In addition, classrooms are equipped with printers, scanners, laserdisc and videotape players, modems, CD Rom drives, and hundreds of software titles.

Long-term data collection allowed us to see gradual shifts in teachers' beliefs about learning and teaching.

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.

This report examines the need for changes in teachers' and students' beliefs about their role in the classroom.

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 bimonthly audio tapes on which teachers reflected about their experiences. Although the study does not include observational data, hundreds of hours of systematic observations by independent researchers support the self-report data reported in this investigation (Gearhart, Herman, Baker, Novak & Whittaker, 1990; Phelan,1989; Tierney, 1988) .

The research team transcribed all written communications and summarized the audio tapes. Narratives were divided into episodes, and episodes were indexed for retrieval using a variety of categories and subcategories, allowing for sorting and rapid retrieval of data. 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). Important themes and events emerge from the data in the "constant comparison" mode (Glaser & Strauss, 1967). The data were divided into two databases, which together held almost 20,000 episodes. *Double Helix*, a relational database, was used to manage and analyze the data. [For a thorough description of our methodology refer to Ringstaff, Sandholtz, Keirns & Grant (1990)].

Initially, some teachers were uncomfortable about knowing only a little more than the students about technology.

Because the project spanned five years, some of the teachers represented in the database were not involved for the entire time, and simply examining individual teachers' data in terms of chronological dates could have been misleading. Instructional practices differed between those teachers who joined the ACOT project at its inception, and those who began when the project was well underway. Also, each year of the project brought about changes in site organization, in available equipment, or in project goals. At some sites, teachers worked with the same students over several years, while at other locations teachers had to start each year with new students. So, instead of charting individual teachers, we viewed the data collectively, documenting shifts in teacher and student roles during the evolution of the project.

Students spontaneously provided teaching assistance to peers and teachers. Even first graders taught their friends how to boot a disk or maneuver a mouse.

Team teaching, interdisciplinary project-based instruction, and individually-paced instruction became more common at all of the sites.

At first, students - not teachers - initiated peer tutoring. Eventually, teachers capitalized on students' technological expertise. Some teachers assigned students to become experts with specific software.

Initially teachers allowed only their "most capable" students to peer tutor.

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 ACOT classrooms continued to rely on traditional teaching strategies during the early years of the project, despite radical physical changes in their classrooms. 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 (Berman &

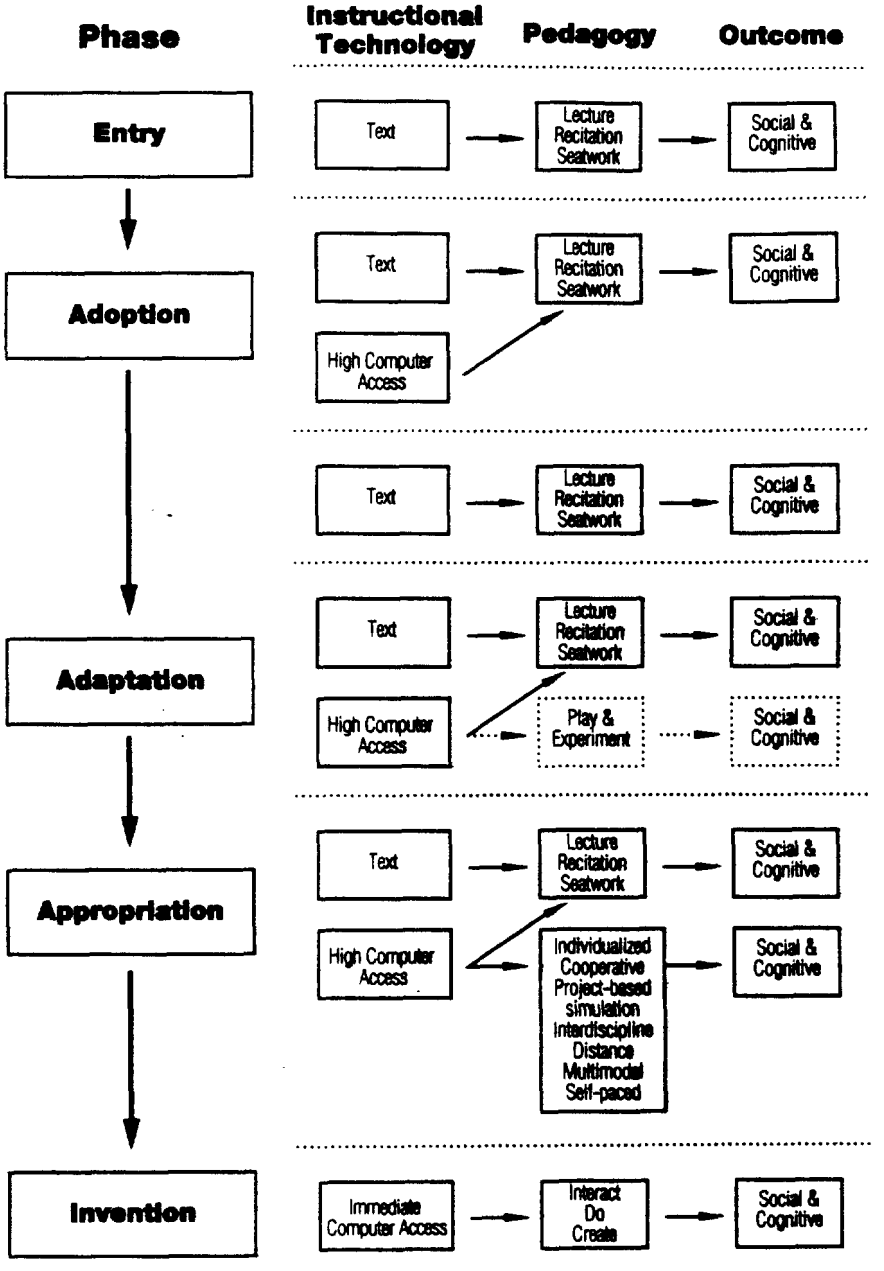


Figure 1. *Instructional Evolution in Technology-Intensive Classrooms*

Gradually, most teachers realized that "slower" students had much to offer their peers.

Teachers soon realized the benefits of the role shift: slow students blossomed, unpopular students gained peer approval, and unmotivated students stayed in to work at recess.

One student discovered "a novel solution to this problem. He is not a 'breakthrough' kind of kid ordinarily. There's something there that I've never been able to pull out before." — A Teacher

At one site, children used computers to help teach their parents to read.

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 (Dwyer, Ringstaff, & Sandholtz, 1991).

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.

This study provides an in-depth analysis of one aspect of instructional change—the willingness of teachers to relinquish their role as expert and utilize student knowledge. It examines how and why teachers began to utilize student expertise, how the roles of student experts expanded as teachers recognized the benefits of peer interaction, and how changes at the classroom and institutional levels reinforced teachers' decisions to utilize student expertise. Also, this report examines 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.

Utilizing Student Expertise in the Classroom

At the outset of the project teachers and students faced learning how to use a multitude of technology tools. Some teachers felt discomfort about knowing little more than their students about the technology. 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 providing spontaneous technical assistance to their peers and instructors. 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 software packages to different students, asking each one to become an expert on a particular application or tool. Other teachers asked students to take software home to evaluate, as in this instance featuring a 10th grader:

One student showed her principal how to use the electronic bulletin board, while others spent after-school time teaching non-ACOT teachers how to use the technology.

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 created his science tests with HyperCard. He quickly realized that one of his students had a lot to teach him:

Some elementary school students were invited repeatedly to create technology classrooms in shopping malls to teach adults.

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 the teacher regularly counted on Sam's expertise when creating tests on HyperCard. Sam provided the "acid test" for 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)

Students were invited to present at numerous state and national conferences.

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

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)

Students were hired by businesses as technology consultants, including one sixth grader who was asked to devise a data system for his town's bank.

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)

Student roles were further augmented when teachers allowed them to present subject matter content to the class.

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 experience with the technology. As it became apparent that students often knew more about it 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, allowing student experts to share their expertise with people other than their peers, and allowing students to teach each other subject matter content as well as offer technological support.

Eventually, the high school teachers began planning entire units in which students, rather than the teacher, presented the content.

A Changing Audience

At home, students often became the family's technical expert. 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." 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!

"The quality of the presentations was unbelievable. The presentations together taught the class about the 50's. It made my job a lot easier."
—A Teacher

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 her principal 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 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:

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 them now, we just assume that a teacher who wants to learn would take advantage of these presentations, but this 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 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 invited 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.

Positive changes occur if there are structural and programmatic shifts at the classroom and school and teachers have many opportunities for self-reflection.

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

In the second year, teachers modified their teaching to take advantage of student expertise.

Student roles were 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)

ACOT staff worked closely with school and district administrators toward institutional change.

Teachers typically found that this student-centered instructional approach took more time than 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)

Teachers frequently used the computer network to discuss instructional issues, provide emotional support and share experiences - decreasing teacher isolation.

In math and chemistry classes teachers abandoned the traditional lecture mode of instruction, asking 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 research suggests 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 shifts were relatively

Unlike many education reform programs, ACOT provided built-in mechanisms that cultivated teacher reflection.

simple alterations that the teachers themselves initiated. 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.

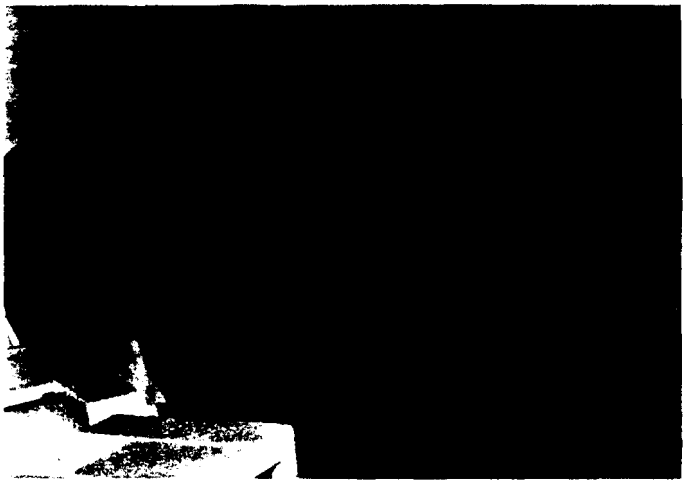
Changes at the Classroom Level

"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."
— A Teacher

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)

"This ... is forcing me to think through my thought processes about what I am doing and questions I am asking."
— A Teacher



Teachers took advantage of student expertise.

Collegial observation re-emphasized the value and importance of their innovative strategies.

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-graders 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)

Technology served as a symbol of change.

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 toward institutional change. Ongoing 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 workshops. Whenever possible, administrators permitted daily schedules to be flexible, allowing for peer observation and team teaching.

"As you work into using the computer in the classroom, you start questioning everything you have done in the past."
— A Teacher

> *The fact that we 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.

Students also had to adjust their thinking about their roles in the classroom.

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)

"More and more we see that the active involvement is what grabs them. That's when they learn something."
— A Teacher

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, ACOT required teachers participating in the project to discuss their experiences on audio tapes several times a month. Although some teachers grumbled about how much time it took, 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.* (#637/1, SL, 11-10-87)

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

ACOT teachers also worked 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:

Students gain a greater sense of ownership in the instructional process when given more responsibility for their learning.

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:

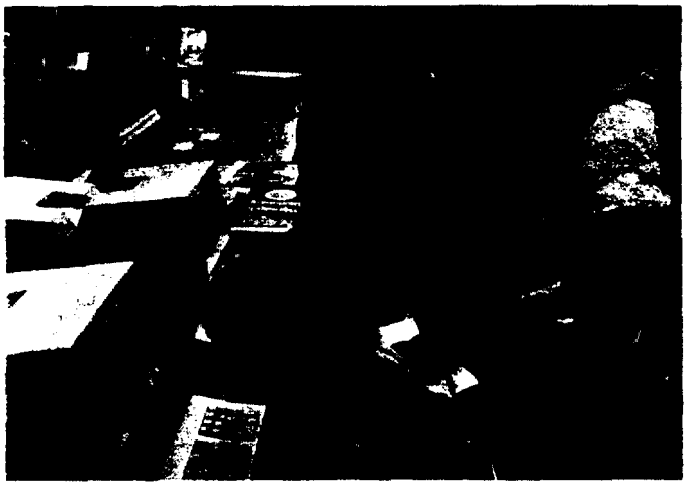
[Working with researchers] lets me know that I am not doing such a bad job, that I do come up with some good questions, and that I am becoming more secure about myself as I become more experienced [at using a new teaching approach]. (#137/2, AT, 9-11-89)

The benefits of using student experts are: teachers are freed from repetitious delivery of basic skills, instruction is personal, academic performance improves, students' self-esteem grows, and parents and educators change their perceptions about the children's talents and capacities.

Periodic visitors to the classroom also 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.

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 this study indicate that the 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.

Those perceived as slow or reluctant learners blossomed when given an alternate avenue for the expression of their knowledge.



Students gain a sense of ownership when given more responsibility for their learning.

These shifts in teachers' instructional patterns cannot be attributed solely to the introduction of technology to classrooms. The technology served as a symbol of change, inviting teachers to re-examine their beliefs about teaching and learning, and their traditional role of "dispensers of knowledge."

In most schools, lecture, recitation, and seatwork continue to predominate instructional practice.

ACOT teachers moved toward child-centered rather than curriculum-centered instruction; toward collaborative rather than individual tasks; toward active rather than passive learning. The process challenged their deeply held beliefs about instruction and gradually transformed them:

> *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)

Movements aimed at creating fundamental education change have seen little success.

> *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. Some students also found it difficult to think of their peers as valuable sources of information:

The ACOT experience illustrates significant change is possible, but requires time, patience, and a high level of support.

> *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, they preferred methods requiring active involvement rather than passive forms of instruction, such as the traditional lecture.

Technology, as a symbol for change, gives teachers license to experiment.

> *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)

During the years we watched ACOT teachers succumb to the sheer necessity of getting help with the technology—even from their students. At first reluctant and uncertain, teachers gradually gained confidence in the benefits of student collaboration.

We observed the increasing frequency of collaborative opportunities for students, the

Only when teachers' underlying beliefs about instruction are altered will serious reform efforts be successful.

move toward allowing students to serve as subject-matter experts, and the expanded audience of these tutors beyond their classmates to include 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.

Customary forms of measuring student achievement may not suffice in classrooms with high levels of peer collaboration.

In countless classrooms across the United States, 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 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 methods 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.

Teachers don't know how to translate students' teaching skills into a grade on a standard report card.

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, an ACOT teacher reflects on the dilemma facing a colleague who is unfamiliar with computers.

Students copy their teachers' instruction style.

> *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, Herman, Baker, Novak, & Whittaker, 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 audio tapes—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.

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,

School districts hesitate to see teachers as resources for instructional improvement.

when students began to deliver content information to one another, they typically taught as they had been taught. One teacher succinctly captured the problem with many student presentations: "Most of [the students] taught the way I probably teach now—too much talking." To be more effective, student experts will have to be provided with instructional techniques that go beyond the traditional lecture-recitation-seatwork model.

There are numerous benefits to allowing lower-achieving students to act as experts.

Just as teachers were at first reluctant to draw upon the knowledge and skills of their students, districts are hesitant to recognize local experts—their teachers—as resources. Instead of using outside consultants to provide in-service 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 being trained realize that the innovation is already up and running in a setting similar to their own.

Students shouldn't be limited to sharing their expertise only with their peers.

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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APPLE CLASSROOMS OF TOMORROW

Computer Acquisition: A Longitudinal Study of the Influence of High Computer Access on Students' Thinking, Learning, and Interactions

Robert J. Tierney Ph.D.
Ronald Kieffer Ph.D.
Laurie Stowell Ph.D.
Laura E. Desai
Kathleen Whalin Ph.D.
Antonia Gale Moss
The Ohio State University

ACOT Report #16

Apple Computer, Inc.
20525 Mariani Avenue
Cupertino, CA 95014

The Study

Six students were closely observed and interviewed extensively for their four years of high school.

The study details the extent to which students use the computer to expand their choices and ways of knowing, sharing and collaborating.

Technology was approached as a means of cultivating new skills.

Begun in 1985, Apple Classrooms of Tomorrow (ACOT)℠ is a research and development collaboration among public schools, universities, research agencies and Apple Computer, Inc. ACOT explores, develops and demonstrates the powerful uses of technologies in teaching and learning. In all ACOT endeavors, instruction and assessment are as integral to learning as technology.

Supporting a constructivist approach to learning, technology is used as knowledge-building tools. As students collaborate, create media-rich compositions and use simulations and models, researchers investigate four aspects of learning: tasks, interactions, situations and tools. The research is formative. The findings guide ACOT staff and teachers as they refine their approach to learning, teaching and professional development. ACOT teachers and students often use the most advanced technologies available, including experimental technologies, to help us envision the future and improve the educational process.

ACOT views technology as a necessary and catalytic part of the effort required to fundamental restructure America's education system. We hope that by sharing our results with parents, educators, policy makers, and technology developers the lessons of ACOT will contribute to the advancement of educational reform.

In this study we followed six students through four years of high school, documenting the impact of unlimited access to new learning tools—such as computers, scanners and videodisc players—on their thinking, their approach to learning and their interactions with others. The students were in two different classes and the years of case studies overlapped. After a total of five years of detailed observations of the students, as well as lengthy general and debriefing interviews, researchers saw dramatic shifts in students' thinking, learning and interaction.

Our goal was to detail the extent to which students use the computer to expand their choices and ways of knowing, sharing and collaborating. We did not approach technologies as ends unto themselves, but in accord with Olson (1974) who suggests that the function of media with new symbol systems is not so much to convey old knowledge in new forms, but rather to cultivate new skills. Or, as Kozma (1991) stated:

> *...the capabilities of a particular medium, in conjunction with methods that take advantage of these capabilities, interact with and influence the ways learners represent and process information and may result in more and different learning* (p. 179).

This study departs from most previous examinations of the impact of computers upon learning. Past studies have been restricted to the use of traditional indices which may not reflect the true nature of computer literacy (Baker & Herman, 1989; Ross, Morrison & Smith, 1989). As Baker, Gearhart & Herman (1990) suggested, traditional indices do not appear to address the types of skills students acquire in high computer access classrooms.

We were interested in computer literacy in terms of its symbolic, cognitive, and social