



*Changing the Conversation About*

# Teaching Learning & Technology

*~A Report on 10 Years of ACOT Research~*



**“What happens when computers become a significant resource in classrooms? How does a critical mass of technology affect the way teachers teach and learners learn?” These were the questions that were raised when the ACOT project began. For more than a decade, researchers, practitioners, and technology developers have been able to work together to increase our understanding of what can happen in classrooms when powerful technology and effective instruction are joined. The lessons learned provide a rich foundation of experience and knowledge to guide current investments in technology at the local, state, and national level.**

*—Linda G. Roberts, Director, Office of Educational Technology,  
U.S. Department of Education*

**Because of ACOT and the technology, I continue to be enthusiastic about being a teacher. But I am an altogether different teacher than I was before. I am now guiding the students. They are the masters of their own education now, creating their own knowledge and using their creativity to research and explain information to others.**

*—Chris Stortz, ACOT Teacher,  
Stevens Creek Elementary School, Cupertino, California*

**What we observed was the reality  
that multimedia and multiple layers  
of information helped students more  
thoroughly and more dynamically  
explore ideas.**

*—Robert J. Tierney, Professor and Chair,  
Educational Theory and Practice,  
The Ohio State University*

**Using technology as a motivator for change and a tool for teaching and learning,  
today's ACOT Teacher Development Centers engage teachers in the same kinds  
of challenging and collaborative learning activities that they aim to provide their  
students. As such, these centers are an evolving solution to the most pressing  
dilemma facing education reform: how to spread the accomplished practice from  
a few teachers and schools to many.**

*—Dr. Jane L. David,  
Director, Bay Area Research Group, Palo Alto, California*

# 1985

## *Initiating ACOT*

*Educators at Apple initiated a research project to answer the question: What happens to students and teachers when they have access to computers whenever they need it? This meant that the technology was always available—not down the hall in a lab, and not left behind when students went home after school.*

*First sites selected—one classroom each in Eugene, Oregon, and Blue Earth, Minnesota. ACOT supplied the computers and trained the teachers. Our district partners paid for staffing, physical modifications to the classrooms, and extra insurance.*

# 1986

*Additional sites were added in Columbus, Ohio; Cupertino, California; Houston, Texas; and Memphis and Nashville, Tennessee.*

*First public presentations about ACOT—at MECC and AppleFest.*

*The ACOT Senior Scholars Conference, attended by a group of distinguished researchers, developed a research agenda for ACOT.*

# 1987

*The sites at Houston and Eugene were closed in favor of adding more classrooms at the other sites.*

*The ACOT Teacher Summer Conference gave teachers at the ACOT sites an opportunity to meet, share experiences, and learn more about teaching with technology.*

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## *1986–87: The start of longitudinal research\**

*We knew that changes in teachers—and in schools—happen over time. During the first two years, we simply observed what was happening in the classrooms.*

- *ACOT teachers used word processing and electronic mail to send weekly reports from each site to ACOT staff at Apple. And each teacher sent monthly audiotape journals to the researchers in which they expressed their personal frustrations as well as their victories.*
- *ACOT researchers developed a database to store the information—without losing any of the descriptive quality—and began looking at major themes.*
- *Eva Baker (UCLA Center for Technology Assessment) began examining the impact of the ACOT program on students, staff, and parents.*
- *Robert Tierney (The Ohio State University) began a longitudinal study of the thought processes of ninth-graders at the ACOT high school site—exploring the potential of technology as a tool to strengthen and expand students' thinking skills.*
- *Elfrieda Hiebert (University of Colorado) collaborated with an ACOT third-grade teacher to describe and assess a computer-intensive writing curriculum.*

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*\*ACOT research reports are available on many of these topics. See “Where to get more information” at the end of this report.*

# 1988

We continued to add classrooms at the sites.

ACOT research studies were presented at the American Education Research Association (AERA), the International Reading Association (IRA), and the International Association of Computing Educators (IACE).

ACOT was featured in a report on the use of technology in American schools published by the U.S. Office of Technology Assessment.

# 1989

We focused on three sites—Columbus, Cupertino, and Nashville—so we could learn more by working intensively with fewer schools. We also continued to add classrooms so we could follow students through more grades.

We published reports on Hiebert's writing research, on the first two years of Tierney's longitudinal study of students' thinking, and on Fisher's study of student empowerment.

We began preliminary work on a teacher development model at the Nashville site.

Visitors from South America and the USSR toured ACOT sites.

ACOT was cited in articles in USA Today, The New York Times, Business Week, Boston Globe, and the Japanese counterpart of PC Magazine, and featured on NBC Nightly News.

## 1988–89: Continuation of longitudinal research

We introduced multimedia at the sites and continued our observations, finding themes that we wanted to address more fully.

- Recognizing that teachers' practice was becoming more learner centered, we began focusing our staff development sessions to encourage a constructivist approach to teaching.
- We started an investigation of the interrelationships among learning, computers, and space.
- We realized the limitations of traditional assessment measures for capturing the changes we saw in the ACOT students.
- We also discovered that the students were developing a variety of new competencies not usually measured.
- We began developing a common language to help teachers collaborate more effectively.

## 1988–89: Expansion of research collaboration

We began funding the work of researchers at other institutions whose projects addressed issues and themes we had found in the observational research.

- In alternative assessment, we began working with Allan Collins (Northwestern University) and Jan Hawkins (Center for Children and Technology) and continued our relationships with Tierney and Baker.
- In writing, we began collaborating on a language arts assessment tool with Midian Kurland (Educational Development Center) as well as on telecommunications-based writing workshops for teachers.
- In task design, we began working with Charles Fisher (University of Colorado) on creating projects that empowered students and on the associated needs for staff development.
- In staff development, we worked with Jean Marsh (Vanderbilt University) on a new staff development model for ACOT teachers.

# 1990

## 1990–95: Amplifying our voice

Realizing that more people needed to hear what we'd learned about teaching and learning with technology—especially about the need for new forms of assessment and new approaches to staff development—we increased our speaking engagements beyond the community of educational researchers. We also began responding to requests for information from state and national policymakers.

We published reports on Baker's two-year evaluation study and Confrey's development of Function Probe and a problem-based mathematics curriculum. We also published our four-year study of the evolution of teachers' beliefs and practices and our study of classroom management—both by Dwyer, Ringstaff, and Sandholtz. And we made presentations on several research projects at AERA.

- Presentations to the U.S. Department of Education, President's National Education Goals Committee, National Governors Association, Education Commission of the States, National Center for Education and the Economy, Fortune 500 Magazine Education Summit, Federal Communications Commission, and Smithsonian Computer-world program
- Presentations at regional and national conferences including the American Education Research Association, American Psychological Association, National Education Computing Conference, Computer-Using Educators, International Reading Association, American Association of Physics Teachers, American Math Society, National Science Teachers Association, and the Cognitive Science Society
- Article in *Educational Leadership* on changes in teachers' beliefs and practices

## 1990–93: Developing integrated environments

Realizing that technology—and especially wireless technology—could have an especially strong impact in the areas of collaboration, communication, and the construction and expression of knowledge, we used the results of our research to create specific learning environments that demonstrated the integration of these areas. Then we produced short videos to document the projects.

- The project known as "Wireless Coyote" explored the use of mobile, networked, and multirepresentational technology—as well as the effects of a constructivist environment—during a science field trip for middle school students.
- The project known as "Cloud Forest Classroom" replicated Wireless Coyote in another location and with other students. For this study, we developed and tested an integrated data collection, data analysis, and messaging environment to support collaborative field activities.
- The project known as MediaFusion involved an integrated environment that allows developers to make conventional TV broadcasts explorable by computer. It gave teachers, students, researchers, and our partners at the Public Broadcasting System (PBS) a view of how interactive TV might someday be used for learning.

## 1989–92: Encouraging new uses of technology

Technological advances now allowed developers to create tools that represented ideas in multiple formats—text, images, video, graphics, tables, and charts. We began collaborating with researchers who were developing multirepresentational tools that could aid in knowledge construction. The product list included Function Probe, Science for Living, Geometry Tutor, Physics Tutor, Digital Image Processing, and TableTop.

We also began working with researchers at the Ontario Institute for Studies in Education on CSILE, a computer-supported collaborative learning environment for children.

## 1990–95: Developing additional partnerships

- With the National Science Foundation, we established ACOT Teacher Development Centers at three sites in order to investigate more fully the effectiveness of this new approach to professional development.
- With the National Alliance for Restructuring Education, we created a network of Teacher Development Centers in participating schools. This allows us to work in environments in which restructuring is already under way and also to see how the staff development model can be replicated on a larger scale.
- With the San Francisco Exploratorium and a local school district, we are investigating how elementary school teachers can use a multimedia messaging system and a media-rich environment to enhance communication, collaboration, and inquiry.

# 1991

# 1992

# 1993

# 1994

# 1995

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- Presentations at meetings of the American Education Research Association, American Psychological Association, and the California Business Roundtable
- Presentations to the commissioners of education and their staffs for Kentucky, Vermont, New York, Indiana, and Ohio
- Presentations to 11 Soviet Republic Ministers of Education

We published a report on five years of Tierney's longitudinal study of the influence of high computer access on students' thinking, learning, and interactions. We also published reports by Ringstaff, Sandboltz, and Dwyer on the relationship between technological innovation and collegial interaction and on the classroom results of teachers using students' technology expertise. We published a report on the school-university-business partnerships that make up ACOT, as well as a report on a second-grade multimedia-composing project.

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- Presentations to several state boards of education and legislators
- Briefings to educators and policy makers from the United Kingdom, Singapore, Japan, Bulgaria, Saudi Arabia, Turkey, Portugal, Poland, United Arab Emirates, Hungary, and France
- More than 25 national and regional newspapers, magazines, and TV stations—including the Wall Street Journal, The New York Times, Forbes Magazine, and Education Week—cited ACOT as a reference.

- Presentations to the U.S. Office of Technology Assessment and the Council of Great City Schools
- Presentations to a variety of educational reform groups, including the New America Schools governing board, National Alliance for Restructuring Education, ATLAS project, and the Coalition for Essential Schools
- Presentations to ministries of education for New Zealand, Singapore, and the European Commission
- Article in Educational Leadership on lessons from ACOT classrooms
- Distribution of ACOT research summaries to 40,000 educators

We published Stuebing's report on physical environments for learning with technology; Ringstaff, Wilmore, and Yocam's reports on the pilot program and first year of the ACOT Teacher Development Centers project; Sandboltz and Ringstaff's report on student engagement; and a report on the MediaFusion project. We made presentations on ACOT-related research at conferences in London, Boston, St. Petersburg, and San Francisco.

- Presentations to ministries of education in Denmark, Sweden, India, Bolivia, Scotland, Great Britain, Chile, Australia, and New Zealand
- Meetings with the commissioner for education of the European Union
- Participation in a PBS series on education

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# 10

## **Initiating ACOT 2000**

*At the beginning of ACOT's second decade, we're both expanding our current work into new arenas and continuing to ask new questions about teaching and learning with technology.*

- *What happens when students have a learning environment in which technology resources are available wherever they're needed—unlike most classrooms, which use desks and desktop computers?*
- *What are the effects of bringing highly innovative math and science curricula into student-centered, constructivist ACOT classrooms?*
- *Can we apply the ACOT principles to a global study of the use of technology for learning?*



*For the past 10 years, Apple has sponsored a research project called Apple Classrooms of Tomorrow (ACOT) that is investigating the relationship between technology and education. The ACOT experience has been unique for us. The research is exploratory and open-ended. And, over the years, it has brought us into partnership with students, educators, and researchers throughout the nation.*

*We'd like to use what we've learned in ACOT to change the conversation about technology and education. Instead of talking about computers, for example, we talk about learning. We describe what happens when students use technology as a tool for building their own knowledge—and examine the impact on the kinds of skills they develop. We discuss how teachers can use technology to create more challenging learning environments—and suggest a staff development process that can facilitate that. And we explore ways to deepen our understanding of how technology can be used as a tool for learning.*

*This is a work in progress. The following report presents some of the ACOT findings and suggests the implications they have for education. But there's always more to be learned.*

A handwritten signature in black ink, reading "David C. Dwyer".

*David C. Dwyer, Ph.D.  
Distinguished Scientist  
Apple Classrooms of Tomorrow*



*It all started  
with a question:*

During the mid-1980s, a time of great excitement about using technology to enhance education, educators at Apple proposed a simple experiment. They would create environments in which technology was used as routinely as paper and books—and then observe the effects on teaching and learning.

**WHAT  
HAPPENS  
TO STUDENTS  
AND TEACHERS  
WHEN THEY  
HAVE ACCESS  
TO TECHNOLOGY  
WHENEVER THEY  
NEED IT?**

Working with partner districts, they selected schools and classrooms, and they gave two computers to each student and teacher—one for school and one for home. (In those days of bulky equipment, this was the only way to provide immediate and routine access.)

From the outset, the investigation team was composed of university-based researchers, ACOT staff members, and teachers—who played an important role in describing classroom changes. With electronic mail and audiotape for communication, and encouragement to reflect on their experiences, the teachers flooded the ACOT staff at Apple with their observations. As the volume of communication grew, the ACOT researchers developed a database for the anecdotal data and began investigating themes relating to technology and change. Researchers from other institutions also began to conduct investigations in the ACOT settings.

**“The students don’t  
get tired of working  
on the computer. They  
actually ask for things  
to do. In all of my  
years of teaching, I  
never had anyone ask  
for another ditto.”**

*–Robert Howell,  
Fourth-grade Teacher,  
Dodson Elementary School,  
Nashville, Tennessee*

*What  
happens to  
students...*

By the end of the first year, students’ behavior and attendance improved, along with their attitude toward themselves and toward learning. Performance also improved in several ways:

- Test scores indicated that, despite time spent learning to use the technology, students were performing well—and some were clearly performing better.
- The students wrote more, more effectively, and with greater fluidity.
- Some classes finished whole units of study far more quickly than in past years.

Dispelling widespread myths, the researchers found that instead of isolating students, access to technology actually encouraged them to collaborate more than in traditional classrooms. And instead of becoming boring with use, technology was even more interesting to students as they began using it for creating and communicating.

Over time, independent researchers found that students in ACOT classrooms not only continued to perform well on standardized tests but were also developing a variety of competencies not usually measured. ACOT students did the following:

- Explored and represented information dynamically and in many forms.
- Became socially aware and more confident.
- Communicated effectively about complex processes.
- Used technology routinely and appropriately.
- Became independent learners and self-starters.
- Knew their areas of expertise and shared that expertise spontaneously.
- Worked well collaboratively.
- Developed a positive orientation to the future.

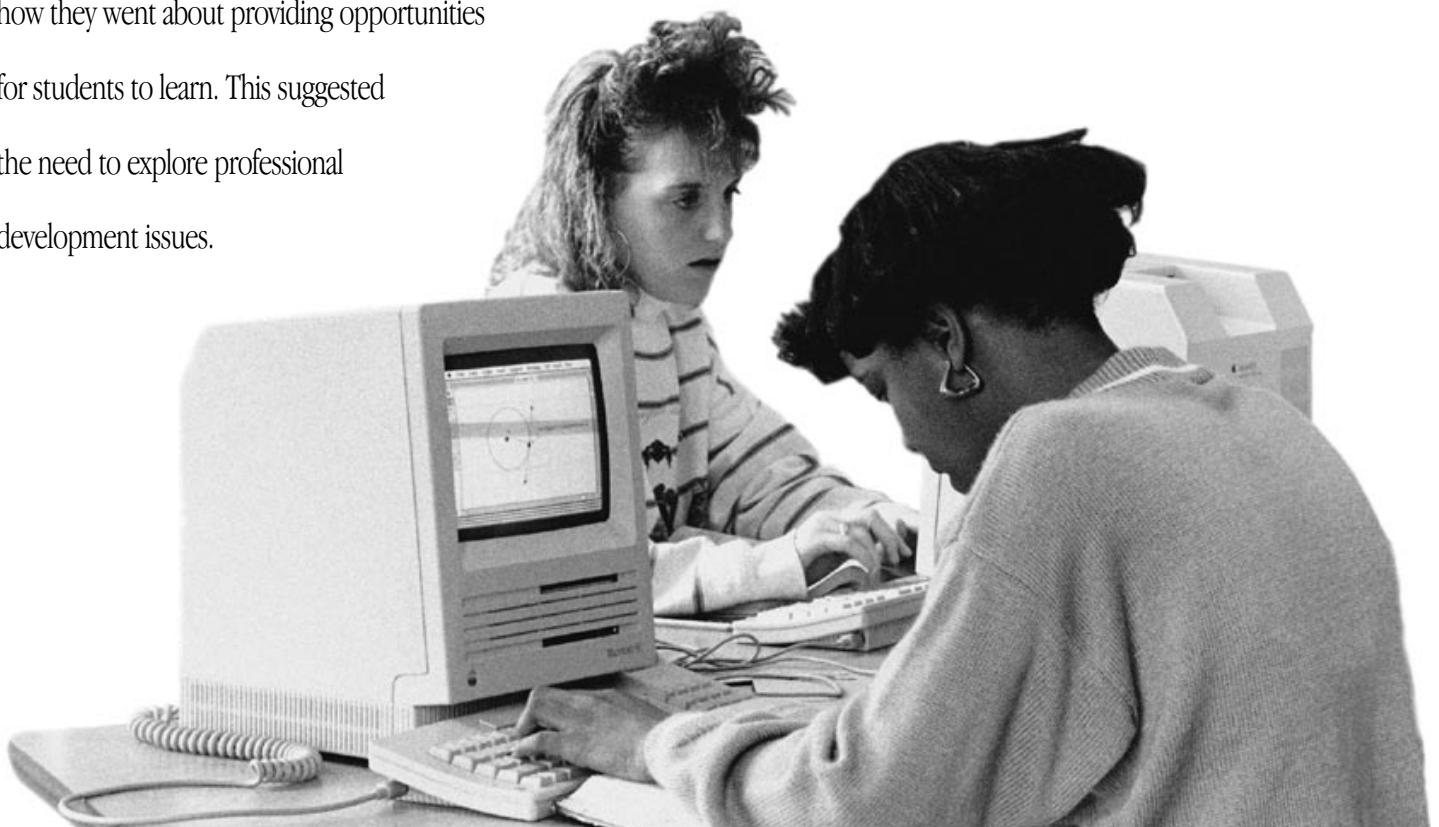
# *...and teachers?*

These findings suggested the need for more research, both in the area of assessment and in ways to develop similar environments for learning in other schools.

As ACOT teachers became comfortable with the technology, they reported they were enjoying their work more and feeling more successful with their students. Over time, they also reported that they interacted differently with their students—more as guides or mentors and less like lecturers. In fact, their personal efforts to make technology an integral part of their classrooms caused them to rethink their most basic beliefs about education and opened them to the possibilities of redefining how they went about providing opportunities for students to learn. This suggested the need to explore professional development issues.

**ACOT has revitalized the teaching process tremendously. It has also been the catalyst for a transition from blackboards and textbooks to a method of instruction where students can explore, discover, and construct their own knowledge.**

*—Barry Stebbins, Science Teacher,  
West High School, Columbus, Ohio*



# *Understanding the role of technology*

Not surprisingly, teachers and researchers found that an array of tools for acquiring information and for thinking and communicating allows more children more ways to become successful learners. But they also found that the technology itself is a catalyst for change—encouraging fundamentally different forms of interactions among students and between students and teachers, engaging students systematically in higher-order cognitive tasks, and prompting teachers to question old assumptions about instruction and learning.



**The ACOT classrooms have become a model for interdisciplinary studies, team teaching, and addressing individual learning styles. These are all concepts that have been around for many years, but that are not easily put into practice. Introducing technology into the classroom provides a catalyst to actually put these concepts into practice and helps both students and teachers to succeed in dramatic ways.**

*—Jane Pratt, Supervisor,  
Department of Instructional Technology,  
Columbus Public Schools, Columbus, Ohio*

The chart below shows the shift that occurred in classrooms as the ACOT teachers extended their traditional views of teaching and learning—from instruction to knowledge construction.

	<b>Traditional (instruction)</b>	<b>Extended (knowledge construction)</b>
<b>Activity</b>	<i>Teacher-centered and didactic</i>	<i>Learner-centered and interactive</i>
<b>Teacher role</b>	<i>Fact teller and expert</i>	<i>Collaborator and sometimes learner</i>
<b>Student role</b>	<i>Listener and learner</i>	<i>Collaborator and sometimes expert</i>
<b>Learning emphasis</b>	<i>Facts and replication</i>	<i>Relationships and inquiry</i>
<b>Concept of knowledge</b>	<i>Accumulation</i>	<i>Transformation</i>
<b>Demonstration of success</b>	<i>Quantity</i>	<i>Quality</i>
<b>Assessment</b>	<i>Norm-referenced and multiple guess</i>	<i>Criterion-referenced and performance portfolios</i>
<b>Technology use</b>	<i>Seat work</i>	<i>Communication, collaboration, information access, and expression</i>

# *What's important to know for today's schools?*

Early on, we found that with powerful, multipurpose tools and a learning environment that balances the appropriate use of direct instruction with a collaborative, inquiry-driven, knowledge-construction approach, students can achieve far beyond today's expectations. We also discovered that teachers are the key to creating such learning environments. And we found that they need broad administrative support both to create these environments and to sustain them.

Although few schools offer the degree of technology access found in ACOT classrooms, our research raises some important points for today's discussions about education. These ideas, though powerful, are also so simple that we sometimes refer to them as "the cutting edge of common sense."

## *Learning needs to be meaningful.*

We need to balance curriculum-based instruction with opportunities for students to use an inquiry-based, collaborative approach to solve meaningful problems. Problem-based learning lets students build on their own knowledge and incorporate new information with what they have already learned. And when technology is available to students, it not only opens up opportunities to solve problems, it also provides additional tools for communication and collaboration.

Examples abound of ACOT students being engaged in meaningful learning activities. For instance, fourth-graders capped a semester of technology-enriched project-based learning by initiating their own writing project. During the last three weeks of the school year, they designed, wrote, and produced "how-to" handbooks for the incoming fourth-graders—to help the new students more easily learn how to use ACOT's technology-based tools.

**This experience has made me take risks. I've decided the worst that can happen is I make mistakes and I need to ask others for help. I think if I show that I take risks and make mistakes in teaching, my children will feel more comfortable doing the same in learning.**

*—Participant in the ACOT  
Teacher Development Center program*

**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.**

—Paula Fistick, Math Teacher, West High School, Columbus, Ohio

Students at the ACOT high school site, engaged in an interdisciplinary study of their city, constructed a mechanized, 12-foot-square, scale model of the downtown area—and honed their skills in mathematics, language arts, and robotics as well as in critical thinking, problem solving, and resource management. Replicating the project the following year, the next class added a level of complexity. After videotaping the entire process, they used the video output to create an interactive, computer-driven exhibit for the city's science museum.

*Technology is a catalyst for change.*

Bringing technology into the classroom levels the playing field between teachers and students—creating an unfamiliar challenge for teachers. This effect is compounded when the students know more about the technology than their teachers—or simply learn to use it faster. Although teachers may initially be uncomfortable in that situation, they also discover unexpected benefits. For example, many teachers develop more empathy for students because they, too, are experiencing being

learners. They also develop new respect for those students who learn enough to become “local experts” in the technology area, and often rely on them to help others.

As teachers become comfortable with a shift in classroom roles, they may start extending their idea of what it means to be a teacher. If they're supported, they may also change their approach to teaching and learning—from curriculum-centered to learner-centered, from individual tasks to collaborative work, and from passive learning to active learning.



**As a result of my experiences at the center, I am now allowing my children to have more control of the equipment. Before, I would have the children type on the word processor, and I'd save it for them. Then, in the evening, I would print their things for them. Now I let them do it all.**

*—Participant in the ACOT Teacher Development Center program*

*Teachers progress through stages as they learn how to incorporate technology in classroom environments.*

We observed that teachers' approach to the use of classroom technology evolves through a few orderly stages: entry, adoption, adaptation, appropriation, and invention. And we found that certain kinds of support help speed that evolution: mentors who are further along in the process, opportunities for reflection, and encouragement to question their beliefs about teaching and learning.

*A framework for collaboration can support teachers in the change process.*

When teachers have an opportunity to collaborate with peers, for example in developing or assessing classroom activities, they have a wealth of experience on which to draw. Yet because teaching is essentially an individual activity, teachers are not used to this kind of collaboration.

So they usually begin with different approaches, points of view, and vocabularies. A common language and framework for discussion makes collaboration on classroom activities more productive and also supports professional growth.

ACOT staff and teachers came up with the following terms and associated questions for beginning a conversation about change:

**Standards.** What objectives are set for learners? Why is it important for a student to accomplish an objective? How does the objective fit into an overall district, state, national, or international framework?

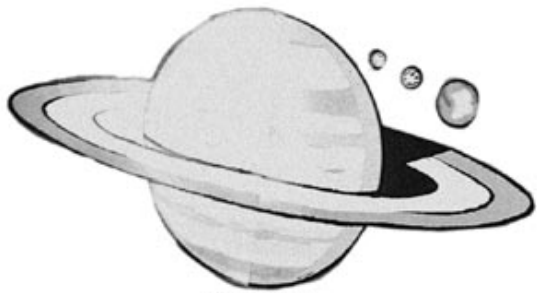
**Tasks.** What is the nature of the student work required by the teacher?

**Interactions.** Who talks and works with whom? Who initiates interactions?

**Situations.** How are time, space, and place—and the experience and concerns of the learner—used to support activities?

**Tools.** What materials are provided to support the representation of ideas?

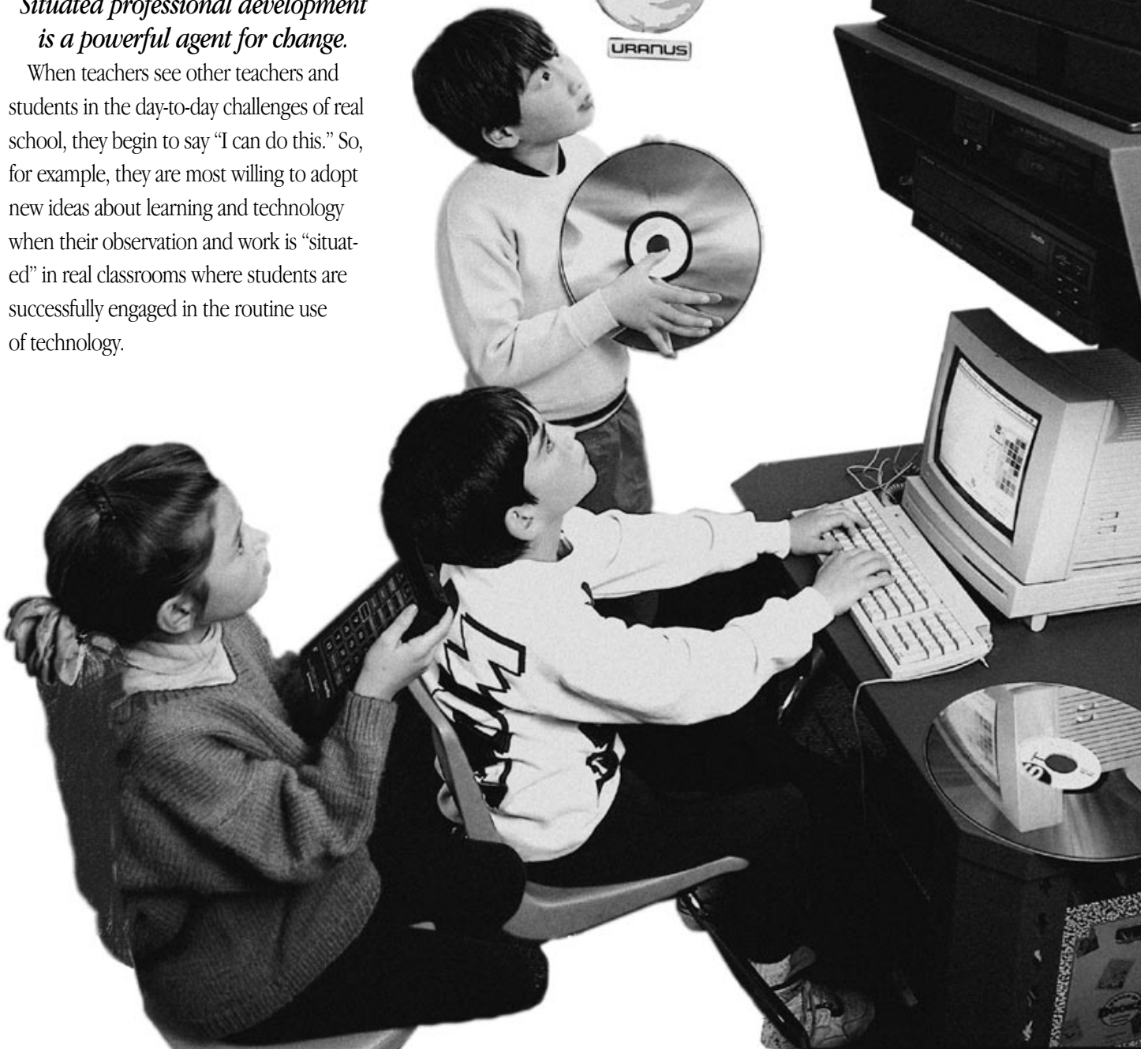
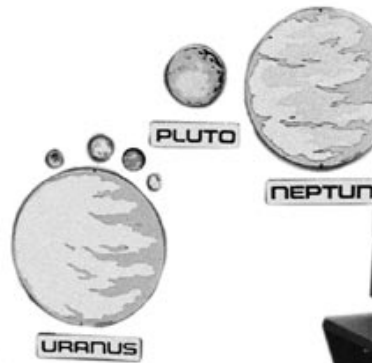
Stage	Examples of what teachers do
Entry	<i>Learn the basics of using the new technology.</i>
Adoption	<i>Use new technology to support traditional instruction.</i>
Adaptation	<i>Integrate new technology into traditional classroom practice. Here, they often focus on increased student productivity and engagement by using word processors, spreadsheets, and graphics tools.</i>
Appropriation	<i>Focus on cooperative, project-based, and interdisciplinary work—incorporating the technology as needed and as one of many tools.</i>
Invention	<i>Discover new uses for technology tools, for example, developing spreadsheet macros for teaching algebra or designing projects that combine multiple technologies.</i>



**Assessment.** How is student learning demonstrated? How do students, teachers, parents, and administrators know that productive work is accomplished—that learning standards are met or exceeded?

***Situated professional development is a powerful agent for change.***

When teachers see other teachers and students in the day-to-day challenges of real school, they begin to say “I can do this.” So, for example, they are most willing to adopt new ideas about learning and technology when their observation and work is “situated” in real classrooms where students are successfully engaged in the routine use of technology.



# The ACOT Teacher

In 1985, when ACOT staff began exploring ways to help teachers use technology effectively in their classrooms, they tried various teacher development approaches. Over the years, they found that those that had the most impact did the following:

- Involved small-group collaborations among teachers
- Took place in working classrooms
- Built on teachers' existing knowledge about curriculum and practice
- Provided opportunities to experiment and reflect on new experiences
- Provided ongoing support to help implement change and innovation

Visitors to ACOT sites remarked on the differences they observed between traditional teacher roles and what they saw in the ACOT classrooms, and they often asked how the ACOT teachers learned the instructional techniques they use.

In 1988, in response to frequent requests for a "recipe for technology staff development," the teachers and staff at the Nashville ACOT site designed a professional development program that would provide opportunities for teachers to learn about integrating technology within the context of classroom practice.

By 1989, two-teacher teams from local schools began attending three-day programs at the ACOT site. During that time,

the participants observed accomplished ACOT teachers and discussed the approach to teaching and learning that the ACOT teachers had adopted. They also had hands-on experiences with technology, discussed their goals for technology integration, and developed a proposal for an effective instructional use of technology in their own classroom. Overall, the three-day program not only provided them with new information, but also encouraged them to think about creating more collaborative, active, student-centered environments. The ACOT coordinator provided ongoing follow-up support, visiting each school to talk with the teachers about their efforts to use technology as well as to change their role in the classroom.

Following two years of positive response to this pilot program, the ACOT Teacher Development Centers project was funded by the National Science Foundation—in partnership with ACOT and the participating school districts. The project began in September 1992.



# Development Centers Project

**The biggest benefit of the Teacher Development Centers is that secondary teachers see first-hand what dramatic improvements can be made with instructional methods other than “lecture, recitation, seat work.” They can see that it is possible to implement positive changes with technology as a catalyst.**

—Elizabeth Sidorenko,  
ACOT Teacher Development Center  
Coordinator, Columbus, Ohio

## *Characteristics of Successful Staff Development*

**Constructivist learning environment.** Although some teachers are initially uncomfortable in the learner-centered environment of the ACOT Teacher Development Centers, most quickly adapt, taking advantage of the opportunity for exploration and discovery to construct their own knowledge about the role of technology in instruction.

**Situated staff development.** Working in real classrooms with real students makes staff development participants better able to see that what they are learning can be useful in their own classrooms. The classroom observations not only provide participants with models of teaching strategies, new ideas, and validation for what they were already doing, they also stimulate discussions of educational issues.

**Time for reflection.** When teachers experience a different kind of learning environment, such as that found in the ACOT Teacher Development Centers, they need time to think about the new information they’re getting. Personal reflection, while participating in a group discussion or writing in a personal journal, helps teachers to question their own beliefs and to begin the process of change.

**Specific plans for change.** To structure their observations and experiences, and to facilitate the transfer of new ideas into their own classrooms, participants at the ACOT Teacher Development Centers plan a project that they will implement upon returning to their schools. The major purpose of the project is to get teachers to use their existing resources.

**Immediate and ongoing follow-up support.** Because new skills need to be reinforced with practice and supported with feedback, the teacher development program includes a two-part follow-up component. First, the centers require that teachers attend in teams, so they can provide each other with both practical and emotional support when they return to their schools. In addition, the project coordinators provide frequent feedback to the participants about the implementation of their projects, and they encourage an ongoing conversation about instructional change.

# Looking at 10 years of ACOT research...

*Just as the original “What happens when...?” question prompted a variety of other questions, so, too, the ACOT research divided into several strands. The longitudinal, site-based strand that grew out of the original question has evolved into a professional development project—the ACOT Teacher Development Centers. Another strand focused on the development of cutting-edge technologies that integrated new ideas about teaching and learning. To facilitate the necessary collaboration among researchers, teachers, and students, ACOT established additional short-term research sites in dozens of other classrooms nationwide.*

*Here are some of the major themes of the research and the directions it has taken. (Note: For the most part, the prototype software used in these projects is not commercially available.)*

*There’s been a significant increase in the body of knowledge about how people use technology for teaching and learning, and ACOT researchers have made valuable contributions. But countless questions are still unanswered, and untold more have yet to be asked. This is a work in progress. Stay tuned.*

**Collaboration.** *We know that using technology both encourages students to collaborate and aids in collaborative work. What kinds of collaborative environments and tools are most helpful?*

- Marlene Scardamalia and Carl Bereiter (Ontario Institute for Studies in Education) created a computer-based environment that supports students in the manipulation and construction of information as they collaborate on projects.
- Brian Reilly (UC/Berkeley, now at Apple) designed a HyperCard stack that manages student work in a portfolio format and allows teachers and students to add comments.

**Communication.** *When learners in the past encountered problems, they had access to only the teacher’s knowledge and information from textbooks and the library. What happens when students have access to other experts, on-line sources of information, and colleagues?*

- With the Technical Education Research Center (TERC) and the Public Broadcasting System (PBS) we created MediaFusion, a project that combined the capabilities of television (timely stories) with computers (interactivity) to create environments where students explore important issues and discuss their discoveries with students in other schools.
- Karla Kelly (Lucasfilm) developed an interdisciplinary curriculum—based on the Foxfire model—that motivates middleschool students to explore their own cultural heritage and to create interactive projects that reflect their life experiences.

# ... as a work in progress

• With the San Francisco Exploratorium and a local school district, we are investigating how elementary school teachers can use a media-rich environment to enhance communication, collaboration, and inquiry.

**Multiple representation of ideas.** *What kind of learning tools can we develop that take advantage of the computer's power to represent ideas in multiple forms?*

- Jere Confrey (Cornell) developed a tool to aid in the discovery approach to teaching calculus. Function Probe allows students to construct relationships between tables, graphs, and equations easily and interactively—and to work with functions in a concrete rather than an abstract way.
- Barbara Buckley (Stanford) created an interactive multimedia simulation to give high school students a deeper understanding of physiology.
- Roy Pea and Christina Allen (Institute for Research on Learning) created MediaWorks, a multimedia database and composing tool that allows students to research, create, analyze, and synthesize a wide array of information.

**Intelligent applications and modeling.** *What are some of the ways to use computing power to support students when they're solving problems?*

- John Anderson (Carnegie Mellon University) created an intelligent computer tutor for geometry that provides a visual toolkit for developing geometric proofs and gives feedback at each step.
- Bowen Loftin (University of Houston) developed Intelligent Physics Tutor, a physics-tutoring

environment that “observes” each student solving problems and “learns” how best to respond to his or her errors and how to provide useful guidance through the curriculum.

**Information analysis.** *What happens to learning and motivation when we give students access to the very tools, or the same kinds of tools, that are used by professional researchers?*

- Chris Hancock (Technical Education Research Center) explored the use of technology to help teach middle school students how to use data to solve real problems. He used TableTop, a visual database environment for young students, and developed interdisciplinary, inquiry-based activities.
- Richard Greenberg (University of Arizona) taught teachers how their students could use digital image processing tools to derive information from satellite photos—thus gaining authentic science experiences.
- Gene Stanley (Boston University) created hands-on activities and simulations so that high school math and science students could be “doing real science” as they learn about probability and random processes in nature—specifically by studying fractals.
- Karen Price (Harvard) developed a video manipulation tool that allowed teachers and students to use video to explore the context in which language occurs.

**Assessment.** *We know that students and teachers are developing new competencies, many of which are not measured by current tests. How can we identify them accurately and measure them objectively?*

- Eva Baker (UCLA) examined the effectiveness of traditional measures of student achievement and student self-concept at capturing changes in ACOT students over time. She also explored objective ways to do portfolio assessment.
- Robert Tierney (The Ohio State University) conducted longitudinal observations of ACOT high school students, focusing on the way they write, organize their work, and attack new problems. He also examined students' self-assessment.
- Allan Collins (Northwestern University) and Jan Hawkins (Center for Teaching and Learning) investigated the use of video in performance assessment of complex learning, such as in physics.
- Midian Kurland (Education Development Center, now at Apple) examined the use of TextBrowser, a technology-based language arts assessment tool that teachers could also use to generate activities based on the students' own work.
- Roy Pea and Jeremy Roschelle (Institute for Research on Learning) created VideoNoter, a software tool that supports researchers in their efforts to analyze videotapes of classroom learning situations. Using this tool, researchers can annotate and later search and gather video segments on a common theme.

## Where to get more information

ACOT research reports, along with videotapes that document three ACOT projects, are available through Apple's StartingLine materials distribution program. Call 1-800-825-2145 for more information or to place an order.

The ACOT Research Portfolio—1990 includes these reports:

- *ACOT Evaluation Study: First- and Second-Year Findings*
- *Teacher Beliefs and Practices Part I: Patterns of Change*
- *Teacher Beliefs and Practices Part II: Support for Change*
- *Teaching in High-Tech Environments: Classroom Management Revisited*
- *Development of Teacher Knowledge and Implementation of a Problem-based Mathematics Curriculum*

Part number: LO1561A Cost: \$5.00

The ACOT Research Portfolio—1992 includes these reports:

- *Computer Acquisition: A Longitudinal Study of the Influence of High Computer Access on Students' Thinking, Learning, and Interactions*
- *The Negotiations of Group Authorship Among Second-Graders Using Multimedia Composing Software*
- *Partnerships for Change*
- *The Relationship Between Technological Innovation and Collegial Interaction*
- *Trading Places: When Teachers Utilize Student Expertise in Technology-Intensive Classrooms*

Part number: L0328LL/A Cost: \$5.00

The ACOT Research Portfolio—1994 includes these reports:

- *Creating an Alternative Context for Teacher Development: ACOT's Two-year Pilot Project*
- *Creating an Alternative Context for Teacher Development: The ACOT Teacher Development Centers*
- *Environments That Support New Modes of Learning: The Results of Two Interactive Design Workshops*
- *MediaFusion: A Tool That Supports Learning Through Experience, Reflection, and Collaboration*
- *Student Engagement Revisited: Views from Technology-Rich Classrooms*

Part number: L00804/A Cost: \$7.75

Two-page summaries of many of the research reports are available free, either by fax or electronically on the Internet. To order by fax, call Apple Education at 1-800-800-APPL (2775) and choose the fax option. Then follow the instructions to order a catalog of available documents.

To find the summaries (and some of the full reports) on eWorld, located on the World Wide Web, look in the Learning Center.

For information about Apple Education products, programs, and services, call 1-800-800-APPL (2775).

Apple Education information can also be located on the Internet: <http://www.info.apple.com/education>

“**Wireless Coyote**” is a videotape that follows middle school students on a science field trip into the Arizona desert. The students use wireless communications and mobile computers to collect and analyze data and to share their findings with colleagues at other locations. Part number: APL 870 Cost: \$8.00

“**Cloud Forest Classroom: An Investigation into Wireless Collaboration**” is a videotape that shows how students on a biology field trip to Costa Rica's Monteverde Cloud Forest used Macintosh PowerBook computers connected by radio frequency modems to inquire and collaborate.

Part number: APL 882 Cost: \$8.00

“**MediaFusion: Coast-to-Coast Collaboration**” is a videotape that shows how junior high students on opposite coasts of the United States share thoughts and theories about global warming. Using Macintosh computers, the students compose QuickTime movies with embedded graphs that support their positions. Then they exchange these messages via satellite with their peers across the country. Part number: APL 883 Cost: \$8.00

## *We couldn't have done it without you...*

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*...and the thousands of ACOT students and their families.  
Thanks for joining us in this first decade of discovery.*

**ACOT has been a pioneer in providing a national test bed for innovation in advanced educational technologies and in education research. It has fostered new models of uses for technology in education and inspired teachers, researchers, and industry alike.**

*—Roy Pea,  
Dean of the School of Education and Social Policy  
and John Evans Professor of Education and the  
Learning Sciences, Northwestern University*

Apple Classrooms of Tomorrow (ACOT) is a 10-year-old research and development collaboration that unites public schools, universities, research agencies, and Apple Computer, Inc. In ACOT classrooms, students and teachers have immediate access to a wide range of technologies, including computers, videodisc players, video cameras, scanners, CD-ROM drives, modems, and on-line communications services. In addition, students can use an assortment of software programs and tools, including word processors, databases, spreadsheets, and graphics packages. In ACOT classrooms, technology is viewed as a tool for learning and a medium for thinking, collaborating, and communicating.

ACOT research has demonstrated that the introduction of technology to classrooms can significantly increase the potential for learning, especially when it is used to support collaboration, information access, and the expression and representation of students' thoughts and ideas. Realizing this opportunity for all students, however, requires a broadly conceived approach to educational change that integrates new technologies and curricula with new ideas about learning and teaching, as well as with authentic forms of assessment.

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