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AUTHOR Tierney, Robert J.; And Others
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ABSTRACT

In this study, six students were followed through 4 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 5 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. The goal was to detail the extent to which students use the computer to expand their choices and ways of knowing, sharing, and collaborating. This study departs from most previous examinations of the impact of computers upon learning, in that traditional indices are not used to address the types of skills students acquire in high computer access classrooms. The focus is on computer literacy in terms of its symbolic, cognitive, and social dimensions. This study identifies eight student competencies or abilities: dynamic exploration and representation of information; experimentation and problem solving; social awareness and confidence; effective communication; computer use; independence; expertness and collaboration; and a positive orientation to the future. (Contains 5 references.) (Author/ALF)

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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

Authors
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

Research

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)[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.

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

This study identifies eight student competencies acquired during the four years. The abilities are: dynamic exploration and representation of information; experimentation and problem solving; social awareness and confidence; effective communication; computer use; independence; expertness and collaboration, and a positive orientation to the future.

dimensions. Our claim is that just as individuals acquire literacy in ever expanding ways, so computer acquisition proceeds.

This study identifies eight student competencies or abilities: dynamic exploration and representation of information; experimentation and problem solving; social awareness and confidence; effective communication; computer use; independence; expertness and collaboration, and a positive orientation to the future.

Those competencies are remarkably similar to skills identified by the U.S. Department of Labor as critical to the workplace if the United States is to maintain its economic and competitive strength. In June, 1991 the Labor Secretary's Commission on Achieving Necessary Skills (SCANS) identified five minimum competencies: the ability to work with others; acquire and use information; identify, organize and allocate resources; understand complex inter-relationships, and work with a variety of technologies.

The Setting

The site for our study was unique. Many studies on the impact of computers have been restricted to a brief time frame (rarely beyond a month or a semester) during which most students have access to a limited number of computers. This study looked at the impact of computers on students who had continuous access to computers at school and at home. Past studies have also been restricted to studying whether or not one set of individuals are different from another set. This longitudinal study allowed for the assessment of individual shifts in student learning over an entire high school experience.

Six students were from a randomly chosen group of 60 students matching the community's socio-economic status.

In their review of research on media and learning, Clark and Salomon (1986) suggest that one of the drawbacks to studies of the impact of media is that very few situations provide the sustained daily engagement with technology that will afford a reasonable assessment of the impact of technology. The Apple Classrooms of Tomorrow site seemed to provide the investment that Clark and Salomon were calling for, with as much access to computers as students in regular classrooms have to books and pen and paper.

The Subjects

Students have high access to technology and are taught interdisciplinary subjects by teaching teams.

The six students described in this study were from an urban high school, West High School in Columbus, Ohio, and were primarily from working class homes. Representing a cross-section of abilities, they were drawn at random from two classes of 30 students—themselves selected by lottery from over 100 applicants to the program. The first cohort includes students Dan, Teresa, and Michael; the second includes Sandra, James, and Rose.

Most of the classes involved team-teaching situations, (combining such subjects as science and math, or English and history), and lasting 84 minutes.

The longitudinal nature of the study allowed for the assessment of individual shifts in learning throughout high school.

Each student and staff member had the use of a Macintosh® computer at home and at school. They had access to a wide range of software: spreadsheets, word processing, programming, desktop publishing, video editing, multimedia, and databases. Other hardware included printers, laserdisc players, scanners, and an overhead projector capable of displaying a Macintosh screen onto a six-foot screen. Some key hardware and software tools were introduced during the course of the study. In the first class, HyperCard® was not introduced until their junior year, and video capabilities were also limited. Students were also unable to use some of the software at home because of memory limitations.

Data Collection and Analysis

Observations and interviews served as the cornerstone for the study. General interviews were used in hopes of providing details of the students' attitudes, expectations, perceptions of learning experiences, thought processes, and learning outcomes.

Each year observations were made of units of study in which students were using the technology hand-in-hand with classwork and assignments. Within 24 hours of the lesson,

Within 24 hours of a lesson, each student was interviewed by an observer.

each student was debriefed on a one-to-one basis with the observer regarding their behavior.

Researchers made two sets of records of classroom and student activity: videotapes of classroom activities, and a running record of the teacher's behavior, class activities, and individual student activity.

Based on the assumption that shifts in the students' vocabularies may represent shifts in their views and experience, a comparison of the use of different words during these interviews, such as "graphics," "friends," and "interface," corroborated these trends.

Desktop publishing, scanning and hypermedia spurred dramatic shifts in how students represented and integrated ideas.

The use of TEX, a HyperCard application, provided frequency counts for word use by year. These counts were seen as complementary to our other analyses, representing only what was said, not what was felt, thought, or done.

Results

The Impact of High Computer Access Upon Thinking and Learning

With the introduction of desktop publishing, scanning capabilities, and hypermedia[1] some dramatic shifts occurred in how students represented ideas and approached the integration of ideas from various sources.

In the ninth grade, as students began using word processing software and spreadsheets, they viewed technology mainly as a vehicle to edit text and produce typewritten instead of handwritten copy. Most seemed committed to learning about computers and helping one another, but had only a vague sense of the possibilities.

As their perception about technology evolved, they developed a sense of their own expertise.

By the eleventh and twelfth grades their perspective had greatly expanded, and their goals for the technology transcended the classroom. Some had begun using it to help family members with projects, or even for their own profit. All of the students felt their computer expertise would be advantageous in the workplace or college.

They also seemed to have a sense of their own expertise, a recognition of various functions technology could serve, as well as an appreciation of the skills they needed—including the ability to work with others. In terms of their appropriation of the technology, the introduction of desktop publishing, scanning capabilities, and hypermedia contributed to some major shifts in how students represented ideas and approached the integration of ideas from various sources.

Multimedia technologies contributed to major shifts in how students represented and integrated ideas.

A Changing View of Text

"View of text" refers to students' views of the representation and communication of ideas, including the interface between pictorial and orthographic systems.

During the first year of the project, students continued to approach text in a limited fashion. Layout was predetermined and conventionalized, subject matter was linear and non-layered, and the audience was merely an afterthought.

By 11th and 12th grade, students' technology goals changed and transcended the classroom.

In her freshman year, Teresa referred to "accuracy and neatness" as the major attributes of the computer. There was little, if any, mention of graphics or varying formats. Similar comments were made by students in the second group, but they began to explore a few techniques, like boldfacing a story title to contrast with the text.

By years three and four, the research team began to note a shift in students' views of how a document represents and communicates ideas. Students in both groups wanted their projects to be more engaging than traditional texts. This was especially the case for James and Dan, who experimented with graphics, sound and animation. James commented:

> *A lot of times I make my own graphics. When you watch TV you always see really neat graphics and the way they present it —I get an idea from that and I'll see how to do it and it's pretty neat.*

1 Hypermedia refers to various forms of software, including HyperCard, which double as programming environments, and allow the development of non-linear, multi-layered documents.

By the third and fourth years, students' views of how a document communicates ideas shifted.

In the eleventh grade Dan described how he matched text to form:

Now I incorporate graphics with my text a lot more. I relate it or I try to link it together so that it looks like one unit. Like the text and the graphics are just one object. I try to make it look more aesthetic and I try to have it more pertinent to what the text is.

In the twelfth grade, his view of text became even more dynamic:

...the things that we created weren't really something that could be done on a page. They could be printed out but they still wouldn't be the same, like clicking on a button.[2] *It wasn't something you could look at; it was something you had to become involved with....I think it makes it more nonlinear sometimes...Like they'll be showing a process on a computer screen.*

I tried to find some graphics that would appeal. I tried to figure out how to do animation so it wouldn't be too boring. I tried to make it as fresh as I could.

Students wanted their work to be more engaging than traditional texts.

In years one and two, Michael's texts were largely devoid of graphics except to enhance the look of a page, but in years three and four graphics had become integral to exploring and sharing ideas:

I think pictures tell a thousand words. That's true—I love looking at pictures because they tell you a lot more than what you read, I think, so I think the visual part is important, the graphic, because without them it gets boring.

"I tried to figure out how to do an animation so it wouldn't be too boring. I tried to make it as fresh as I could."
— Rose, 10th grade

During her sophomore year, Rose felt limited by the technology.

A lot of times I think of this great wonderful thing, but then I don't think I can do it. So I change my mind, and I have it started and I say no, I can't do that. I have to do something different. I think probably all those things influence what I'm doing.

(Technology) "gives you more to do, more to think about.
— Rose, 10th grade

As she gained confidence, Rose began to recognize the possibilities of the technology.

I don't really think of learning with it any more. To me it took the place of pencil and paper...It gives you more to do, more to think about...It gives you a bigger choice of what you can do. There are so many different ways. You could show what you're trying to say, what you've learned...

You can use HyperCard to make it animated, and anything you really wanted to do. The other kids (outside of ACOT) just have one or two choices the teachers give them and that's the first thing they usually ask us when we're working on a project, "What technology are you going to use?" And you can use the PC viewer to present it. You can do almost anything.

Students wanted to use graphics to create a more professional look. Sandra stated:

Like in PageMaker or something I'll use graphics. Take ideas from magazines and stuff so that now it looks more professional, more laid out.

Students also realized the possibility of developing "dynamic" rather than "static" texts. The result was the creation of non-linear and multi-layered electronic documents, sometimes embedded with "buttons" which linked to other layers of information.

Ideas were no longer treated as one-dimensional and sequential. The students began considering how the issues they were wrestling with might be explored across an array of still

[2] Buttons are a feature of the HyperCard program. Students can create customized buttons which, when selected, allow someone reading a document off the computer to connect to another section of text or graphics, or an animated sequence.

Students created non-linear, multi-layered electronic documents.

pictures, video segments, text segments, and sound clips. Access to technology increased their ability to entertain different perspectives.

These tendencies were also apparent in the word counts. In year one, the words "type," "read," and "write" were used frequently, but words like "create," "stack," "graphic" and "animation" were not. By year four, the words "layout," "multimedia," "graphic," "project," "show" and "see" emerged. Figure 1 provides a listing of the most frequent content words that students used in their general interviews. The numbers were derived from the frequencies of each word in proportion to the use of the other words in this list combined. It should be noted that these word counts reflect the absence of technologies such as hypermedia, animation and video in the freshman years of both student groups.

Ideas no longer were treated as one dimensional and sequential.

Access to technology increased their ability to entertain different perspectives.

As the second year ended, all students perceived an improvement in their ability to write as a result of using the computer.

	Cohort 1						Cohort 2					
Student	Dan		Michael		Teresa		James		Sandra		Rose	
Grade	9	12	9	12	9	12	9	12	9	12	9	12
multimedia	.000	.005	.000	.000	.000	.000	.000	.02	.000	.001	.000	.002
video	.000	.017	.000	.000	.000	.000	.000	.02	.000	.000	.000	.002
HyperCard	.000	.075	.000	.043	.000	.142	.000	.1	.000	.036	.000	.067
animation	.000	.053	.000	.004	.000	.000	.000	.004	.000	.000	.000	.007
graphic	.008	.048	.000	.015	.000	.024	.038	.081	.000	.007	.000	.006
layout	.000	.001	.000	.000	.000	.006	.000	.009	.000	.005	.000	.001
presentation	.013	.005	.000	.000	.000	.000	.000	.006	.000	.053	.000	.004
show	.000	.013	.000	.023	.000	.018	.013	.033	.067	.009	.01	.015
see	.000	.011	.000	.065	.000	.006	.000	.006	.011	.032	.000	.005
stack	.000	.035	.000	.007	.000	.018	.000	.024	.000	.019	.000	.034
project	.012	.061	.000	.042	.000	.107	.000	.056	.000	.063	.000	.04
create	.038	.04	.000	.004	.000	.006	.000	.063	.000	.021	.000	.01
experiment	.000	.013	.000	.000	.000	.036	.000	.007	.000	.001	.000	.001
write	.157	.12	.313	.131	.361	.201	.282	.117	.41	.143	.32	.083
revise	.013	.014	.016	.000	.000	.006	.000	.002	.000	.003	.000	.006
draft	.017	.004	.000	.032	.000	.000	.000	.004	.011	.019	.062	.001
outline	.004	.005	.032	.000	.000	.000	.000	.002	.000	.001	.000	.001
type	.08	.088	.1	.042	.076	.024	.064	.022	.000	.027	.031	.024
read	.089	.025	.2	.063	.122	.018	.103	.024	.122	.024	.041	.037
applications	.004	.003	.000	.003	.000	.006	.000	.009	.000	.007	.000	.003
goals	.004	.001	.000	.002	.017	.006	.000	.002	.000	.004	.000	.003
change	.047	.039	.133	.047	.046	.039	.077	.041	.033	.073	.041	.032
thought	.225	.036	.033	.072	.092	.054	.09	.158	.233	.273	.227	.339
learn	.029	.097	.000	.108	.038	.095	.000	.058	.000	.068	.000	.046
remember	.025	.004	.065	.025	.038	.012	.077	.000	.000	.008	.041	.042
friend	.008	.012	.000	.02	.017	.03	.013	.02	.000	.013	.052	.036
teacher	.004	.054	.048	.06	.038	.071	.09	.05	.044	.049	.113	.063
family	.012	.083	.000	.011	.009	.024	.115	.022	.022	.012	.000	.018
people	.194	.1	.065	.181	.147	.059	.038	.039	.044	.008	.072	.067

Figure 1: *The first column gives the proportion of selected words used by 9th grade students during interviews. The second column reports the proportion of times the same words were spoken during interviews when the student was in 12th grade.*

Impact on Students' Thought Processes, Overall Approach to Learning, and Reasoning

At the end of year two, all students perceived an improvement in their ability to write as a result of using the computer. By year four, their strategies had shifted toward the inclusion of graphics to either complement or spur the development of their texts.

Students' strategies shifted—graphics were included in documents and often spurred their writing.

As a senior, Dan reflected on his own growth as a writer:

> *In tenth grade I think I started mainly to go from using the computer just to fix small typos, and maybe a word choice here and there, to use it more to compare different versions of a story, or to be able to mix the information together. I think I started to look at it on a larger scale...I'll think about what it is I'm doing the project on and what types of graphics I can find for that.*

James uses paper and pencil for idea generation and note taking, while the computer does the "real" work.

James describes how his approach to projects has evolved through the years: ninth grade was the year to work on writing; tenth grade was scripting; eleventh grade was working with graphics, and twelfth grade was bringing things together.

James uses the computer to make the writing process more efficient. He thinks paper and pencil are useful for taking notes, generating ideas, and personal writing, but the computer does the "real" work, moving past the written word to visuals and special effects. The computer is also valuable for editing spelling and grammar mistakes.

- *Writing—it's nice because you can spell check, and you can type fast, and you can check errors, and correct your grammar, and print it quick. And developing projects—that's the thing that I really like, because it does everything for you. I like to be able to create something that's visual for people so everybody understands what you do. You can set it up and walk away, and it kind of explains it for you. I like that. That's what is nice about a project.*

With paper, notes "are all jumbled up but with a computer, I'll bold it or I'll put it separate. When it comes to study for anything, it's easier to gather the information."
— Sandra, 12th grade

As a ninth grader, Sandra simply used the computer as an alternative to pencil and paper.

> *Writing in the ninth grade was like pulling teeth. I didn't want to do anything on the computer at the beginning of ninth grade because I didn't know the keyboard, and I was fearful of touching it because I might break something. Touch the wrong key and everything....I didn't like writing on the computer because it was never a part of me.*

Within the first year, however, she discovered how much easier it was to revise a paper on the computer. By tenth grade her planning process included thoughts of presentation and her "jot lists" began to include visual as well as factual ideas. In the eleventh grade, her research began with an idea of how the final project would be represented. By twelfth grade she seemed more comfortable with her ability to display her research and began to look at the computer as tool to facilitate that display.

> *...It's like I grew up with computers, now that I've used them for four years. It has become a part of me now that I'm so used to it....Like in the notes it's all jumbled up and everything. You can't really distinguish what's important and what's not, because they're all together like that. So on the computer what I do is, when something is important I'll bold it or I'll put it separate—put a little star by it, and when it comes time for me to study for anything it's easier for me to gather the information together and put it on just one page or something.*

Over the first three years of ACOT, Michael's linear approach to writing remained somewhat the same: brainstorming, writing, and then revising. By year four he was using hypertext to draft his ideas, add graphics, and script the two together.

> *I visualize—I just get the pictures together and the text together and then put it together and then do the scripting.*

Computers engendered confidence in writing. Graphics changed the student's approach to text.

During each of the four years of their involvement in ACOT, all six students went through shifts in their approach to writing reports and preparing presentations. Access to computers engendered confidence in their writing abilities, and the advent of graphics changed their approach to the development and view of text.

High school students often take a dim view of their learning experiences, and their own abilities as learners, if that experience lacks relevance. ACOT seems to have provided these six students with an experience which was different in direction and kind. Their involvement with computers was not seen as superfluous, but integral.

The students' involvement with computers was seen as integral.

In year one, students were hesitant about their abilities, and tentative about their future. By year four, all six students had developed a respect for their own capabilities, and a sense of their strengths and weaknesses.

Here is Dan's view of his own capabilities in the first year:

> *I don't know if you write better. You write more because you don't have to worry about going back and checking for mistakes and fixing mistakes, or something like that. You can always do that later. I'm not sure if it affects the quality of your work or not, it is really hard to judge myself in writing.*

"It's almost second nature now."
— David, 11th grade

By year three, Dan felt more confident with the technology, and personal goals superseded academic expectations.

> *One of my goals was to learn how to use the computer, and learn how to use it with my classes and incorporate it into my courses in a way that would benefit me, and I think I've achieved that. It's almost second nature now...Also, when I started to use HyperCard that opened a lot of new doors for me. Being able to do animation and sounds and all these things.*

Doing collaborative presentations with a computer taught me "how to stand up in front of people and say what I want to say. I've learned technical things but mainly dealing with people."
— David. 11th grade

By the fourth year, all six students had developed a respect for their own capabilities.

Quiet by nature, Dan described how the ACOT experience helped him overcome his shyness.

> *(ACOT) has taught me how to work with people a lot, because I've done a lot with peer projects. I've done a lot of presentations with groups. It has taught me how to stand up in front of people and talk out and say what I want to say. I've learned the technical things with the computer, but I think just mainly dealing with people.*

Above all, Dan valued the challenges that the technology offers, taking pride and pleasure in meeting those challenges. He measured his success by internal standards, not by the expectations of others.

Somebody sees an ACOT student that wants to go to college and a regular student with pencil and paper, I think the computer student might have a lot more of an advantage.
— Michael. 12th grade

A lot of times when I start out, I develop (computer-related projects) for the teachers because they said "you have to do this." But as I go along, I think I do it for myself more. I have my ideas of what I think it should be like. Almost never, when I do something, I almost never say I have to do this according to what they want. I usually do it according to what I want and how I want it to go. And usually it turns out for the best.

He also saw himself as a writer striving to communicate with an imagined audience.

One way it helps is when the teachers assign us to do a project with HyperCard, or a publication, and we have to teach the class. We have to learn more about it because we have to be able to understand it so we can communicate it to other students. To rephrase it in terms we think they'll understand better. We have to go more in depth with that.

(I) "definitely want to go to college instead of wasting what I've learned for four years."
— Michael, 12th grade

He viewed computers as useful tools. He didn't perceive learning how to use the computer as an end unto itself, but rather a means to explore subjects more fully.

Sometimes I think it interferes with the learning of the courses when you have to learn about the computer while you're in English or while you're in biology but I think that is one reason why they made the computer applications class so that they wouldn't have to do do that. They would have a separate class where they could learn about the computer.

Dan wanted freedom to explore in school. He describes a preferred learning environment:

"Actually, I think we're sort of more mature in our thoughts."
— Teresa, 12th grade

I think I might have a few parts of the course where I'd say: 'This is what we're going to learn about. You can learn about it whatever way you want. For this week or month or whatever, we're not going to look at the textbook, and do it this way or make a stack. Just let you go on your own.'

For Dan, the future was an unknown. His learning has been for itself, not for known future goals:

I don't know exactly what I'll be doing, what kind of job I'll be having, but I think I'll be using at least one or two things that I've learned in ACOT, whatever it is.

Michael appeared to be an externally-directed learner with a clear sense of his future. He also saw learning about the computer as necessary for future success.

I am planning to go to college and to use the computer. I just made up my mind when I first started out—I always said, "I'm going to be a professional man."

I like the program. And you know some year, if everything works out right and somebody sees an ACOT student that wants to go to college and a regular student with pencil and paper, I think the computer student might have a lot more of an advantage.

I have definitely become more college-minded. Definitely want to go to college instead of wasting what I've learned for four years.

Teresa was proud of what she had learned and what she was capable of doing with the technology. In year four, she said:

(ACOT) made me understand the world a little bit more. Because I know what is going on. I can do stuff like business people do.

Like I said, it's made my writing better. More thought out. Actually I think we're sort of more mature in our thoughts.

"I have no idea what I'll be, whatever I do it will be with computers. I know that."
—James

"Being in ACOT, it makes you more creative. Projects are really your own creation instead of having all these rules you have to follow."
—Sandra

Teresa also saw learning the computer as a valuable skill:

It will probably help me in the career field that I've chosen...I want my career to have something to do with computers, since I've had this fascination with computers since I've been in the 8th grade.

James expects to use his knowledge of computers to assist in getting good grades in college and to gain part time employment teaching the computer to others:

If I go to Ohio State, hopefully I'll get a full ride and I'll be teaching and if I'm teaching computers then I'll be back into—I'll be running in and out teaching everyone else how to use the computer.

I like doing media. I like doing graphics. I like doing—just using the computer to help. I was thinking of going into aerospace engineering. But I have no idea what I'll be. Whatever I do it will be with computers. I know that.

Sandra and Rose looked at their experiences with technology as preparation for college. Sandra noted that the teachers during the past year had been emphasizing multiple approaches to problem solving and had been trying to encourage students to discover their own answers:

I think being in ACOT, it makes you more creative. You have the freedom to almost do anything you want. Like the projects are really your own creation instead of having all these rules you have to follow. Most of the time you can take it in any shape you want. I guess that's what I like about it.

The data suggests computers don't isolate students from each other.

Over the four years, Sandra developed a better sense of what she needed to do to be successful in her written work, and acknowledged a rise in her level of confidence.

I think I've improved in how I communicate through writing. My ideas—I think they're clearer than before.

I think I've gained more confidence—I used to be this kid in a corner who doesn't speak up for anything and people wouldn't know if I was in the room or was not. I think I got more confident and I learned to speak what I feel is strong and let others know that.

By her senior year, Rose saw a strong connection between what they were learning in the classroom and what happens outside of the classroom:

The computer became a way of achieving immediate and long-term goals.

I didn't expect to have all this stuff and everything and I never, ever thought that I was going to be creating—not just working—but creating stuff, because that's one thing I thought we wouldn't get. You're not just working—you're creating a spreadsheet...it was really neat when you know how to do things that you see out in the world.

It's like they (people outside of ACOT) don't think we designed all this. They think we took this little computer and pushed little keys and buttons and made something work like the geometry disk or something. They don't think we created the whole thing. We made the buttons. We made all this. We really had to explain it to these people.

Although some may perceive working with a computer isolates students from one another, our data suggests this isn't true.

Taken together, the comments of the students reflect an appreciation of the meaningfulness of their learning experiences, including an awareness of the computer as a powerful tool which gave them a way to achieve their ends. That is not to say they might not have achieved these ends by other means, but the computer had become a vehicle for achieving a range of goals—both immediate and long term. The computer enhanced their ability to do problem-solving and communicate ideas effectively, to use alternative symbol systems, to establish goals for themselves, and to perceive strengths and weaknesses of their work and experiences. They also recognized a long term advantage: the relevance of the skills they had acquired for career aspirations and for the achievement of personal goals. At the same time, their experiences were individualized. All six students had different goals and dispositions which defined, to some extent, what they gained, as well as where they saw themselves headed.

Working as teams gave students opportunities to interact, share ideas and help each other.

Social Dimensions of Computer Literacy

Literacy is a social act. Oftentimes what is written, dramatized, or symbolized is intended for others; usually it has involved others in the selection and formation of ideas. Students' engagement with computers is no different.

The initial reaction to group work was "oh no." But students discovered "it brings us closer together."
— Sandra, 12th grade

Although some may perceive that working with computers isolates students from one another, data from our case studies suggest this is not the case. All of the students in this study believed that using computers involved complex social dimensions. They engaged in a number of collaborations and assumed a range of roles.

Dan often found himself cast in the role of the expert, advising others on software use, which spurred his own pursuits:

Well, one thing, especially when the class is new, (sharing information) helps build confidence and friendship among the people, because no one knows what they're doing. But there will be a few people who catch on quicker and people will be asking them 'how do you do this' or they'll be offering help—the ones who have learned it faster. So it's one way to meet people.

If we are to come to grips with understanding computer literacy, we need to understand its dynamics - including the social dimensions.

My friends in ACOT, they're in it so they understand what it's all about. I have a lot of friends who aren't in it. And they think it's neat too. That I can do some stuff. Sometimes I work with them on projects using the computer, like I just got done working on a newspaper where I worked with a lot of people I knew. Sometimes I'll offer suggestions like: 'I could show you how to do that on the computer a lot easier' things like that. It's kind of just the sharing of ideas.

The students in ACOT, according to James, constantly worked together in groups. Sometimes they worked with friends, other times they were assigned partners. The groups generally met, discussed an idea or topic, divided up the work and then came back together to compile their findings. During the compilation process, they often sat together as a HyperCard stack was created and took turns controlling the mouse. Finally, they presented their work as a group.

Working together in groups gave students opportunities to interact, provide assistance, and share ideas. James saw the sharing of ideas as important to the success of a project. He

The results from ACOT are different than most education initiatives where results are limited to what is directly taught.

The ACOT experience resulted in marked and provocative differences.

We hope that this study suggests a way of beginning to look at students involved in technology in terms consistent with the possibilities, the changing nature of the media, and the nature of development that may occur.

acknowledged that it could be difficult when everyone had different ideas, but it was better in the long run, because the project improved:

> *...they all chip in and work together and you are basically doing the same amount of work but you've got so much more put into it.*

Having spent four years together, Sandra noted that the students were comfortable using each other for support, as well as for academic help:

> *I like that—I mean because we have four years together we know each other a lot. So I feel free to go to anybody I want to talk to and I really know what some people are good at and I guess you know a little bit more about them and you know what kind of person they are. What they like, what they dislike and what they're good at.*
>
> *Before when we start working in groups it's like, "Oh no, working in groups." And now, from doing a lot of projects together and everything, it brings us closer together and I think we work well as a team.*

While these observations and interviews of the students are not comprehensive, they suggest that the students are engaged in a range of different forms of collaborations (side-by-side pursuit of similar projects, joint construction, problem-solving and coordinated efforts) for a variety of different purposes, and that these collaborations are an integral dimension of their learning. If we are to come to grips with understanding computer literacy, we need to understand its dynamics — including the social dimensions.

Summary and Implications

Most examinations of the impact of educational initiatives are somewhat disheartening—results usually are limited to what is directly taught. The results from the first five years of ACOT are different and these differences are marked and provocative. Perhaps one way to understand the nature of these shifts is to consider what the ACOT experience is, and what our study of this experience represents. The study of ACOT is not the examination of whether or not a certain program is effective, but an opportunity to study computer acquisition in an environment where individuals can explore and participate in its uses. Our description of these students across their four years in ACOT assumes the character of shifts which occur as individuals become computer literate.

The students in both cohorts became independent and collaborative problem-solvers, communicators, record-keepers, and learners with the computers. The ACOT environment invited students to interact with their teachers and peers in a number of projects, and gave them the opportunity to engage in productive and creative experiences, rather than activities or assignments which were overly prescribed and rote. They developed a repertoire of abilities which allowed them to explore possibilities that would be either too cumbersome or difficult to attain without the technology. While they had the capability of achieving their independent agendas, their approach to learning was collaborative. They were engaged with the computer as specialists, team players, artists and craftspersons, and it contributed to their vision of their futures, their social strategies and self-confidence.

We hope that this report has captured some of the character of these shifts: 1) shifts in students' approaches to the development of documents; 2) shifts in how knowledge may be represented via multi-layered and dynamic graphic interfaces; 3) shifts in experimentation, for accessing ideas, as well as thinking through topics; 4) shifts in how ideas were communicated to teachers, classmates and friends, as well as self; 5) shifts in students' goals and view of themselves as learners with different dispositions, varied aspirations, interaction styles, backgrounds, and desires. In addition, we hope that the study suggests a way of beginning to look at students involved in technology in terms consistent with the possibilities, the changing nature of the media and the nature of development that may occur.

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APPLE CLASSROOMS OF TOMORROW

Apple Computer, Inc.
20525 Mariani Ave.
Cupertino, Calif. 95014
Phone: 408-862-5134
Fax: 408-862-6430
AppleLink: ACOT

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