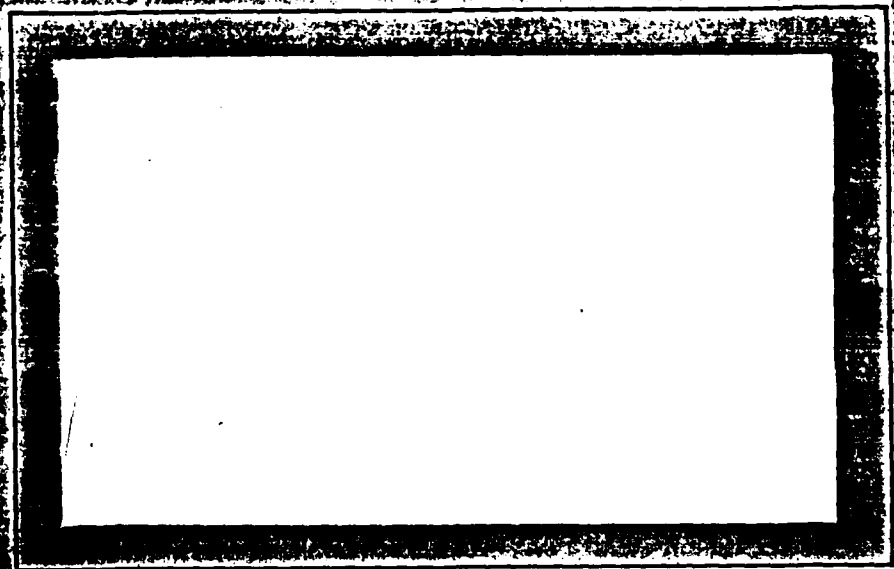


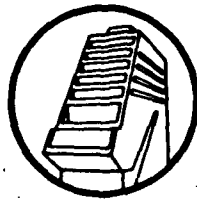
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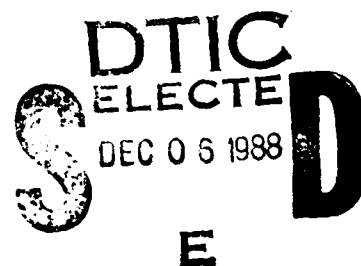
Barriers and Incentives To Computer Usage in Teaching

Janet Ward Schofield and David Verban

Learning Research and Development Center
University of Pittsburgh
Pittsburgh, PA 15260

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extent it may markedly influence important aspects of classroom structure and functioning. For example, there was reason to believe that heavy use of at least certain kinds of software led to a shift in grading practices and changes in the amount and type of attention given to students of varying achievement levels.

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BARRIERS AND INCENTIVES TO COMPUTER USAGE IN TEACHING

Anyone with even the slightest familiarity with the American educational system in the 1980's is well aware of the incredibly rapid proliferation of microcomputers in schools at both the elementary and the secondary level. The magnitude of this change is, however, truly startling. For example, in the two year period from the spring of 1983 to the spring of 1985 the number of computers in schools which had at least one in 1983 more than tripled. By the end of that period almost all secondary schools and five-sixths of all elementary schools in the U.S. had computers for use in instruction (Becker, 1986).

Although the remarkable rapidity with which microcomputers are being placed in schools is obvious, the effect of this change on teachers, students, and on school systems is not. In fact, opinions vary dramatically on what impact computers can or will have. At one extreme are those who see computers as having the capability to revolutionize education in absolutely fundamental ways. For example, Walker (1984, p. 3) makes the rather startling claim that "the potential of computers for improving education is greater than that of any prior invention, including books and writing." Others take quite a different stance, emphasizing the inherent conservatism of the teaching profession with regard to pedagogical change and the failure of other highly touted educational innovations to bring about far reaching changes.

The fevered rush toward acquiring microcomputers means that many teachers now have available to them a tool with which they have little or no familiarity. Further, the fact that major expenditures are being made on computer hardware at a time when many school systems have been feeling a financial pinch has led many systems to skimp on teacher training and support services. In addition it seems apparent that school systems sometimes buy computers in response to parental pressures or because they want

to gain prestige by being at the forefront of a new trend (Taylor & Johnson, 1986) rather than because they have a vision of the educational goals the computers will help them achieve or of how the change process can be handled in a way which maximizes the potential benefits of using microcomputers in instruction while minimizing negative effects. Thus we would argue that more valuable at this point than extra hardware is reflection and research on precisely what schools can accomplish with microcomputers and how this can best be achieved. The goal of this paper is to make a contribution to this general effort. Specifically, we would like to discuss what we believe are some serious impediments to computer usage in schools. In addition, we would like to suggest that computer usage can change fundamental aspects of teacher behavior in potentially important ways.

The thoughts and observations contained in this paper grew out of an intensive ethnographic study of microcomputer usage in one particular high school. There are several very real strengths to an ethnographic approach as a means for stimulating thought about microcomputer usage in schools. First, one of the defining characteristics of this approach is its flexibility and openness. Specifically, although such investigations start with some basic themes or questions in mind, the primary goal is to discover what is important in a given situation rather than to test a set of hypotheses which have been formulated in advance. Thus qualitative investigations can easily be shaped to explore unanticipated issues. Such an approach is highly desirable when little is known about the phenomenon under investigation, as is clearly the case with questions regarding the usage of microcomputers in educational environments.

Qualitative methods are also particularly well-suited to exploring the context in which the phenomena under investigation occur, to suggesting ideas about social

processes, and to capturing with both vividness and subtly the perceptions of the individuals being studied (Reichardt & Cook, 1979; Schofield & Anderson, 1987). Again, all of these attributes are particularly important for the topic to be discussed here.

Although relatively little is now known about the impact of microcomputers on various aspects of schooling, one thing which is clear is that the educational context is very important in determining if and how microcomputers will have an influence. For example, after a close look at computer usage in three rather different school systems, Sheingold, Kane, and Endrewelt (1983, p. 431) concluded that "the effects of microcomputers on education will depend, to a large extent, on the social and educational context within which they are embedded." Similarly, it is clear that social processes in the school will play an important role in influencing how microcomputers influence teaching. For example, Becker (1984) found that the amount and type of microcomputer utilization in elementary school classrooms is clearly related to the relative importance of different actors (teachers, principals, or other administrators) in the acquisition of those machines. Finally, the emphasis that qualitative approaches put on questions of meaning is likely to be especially helpful in understanding the interrelation between teaching and microcomputer usage. For example, research by Sheingold, Hawkins, and Char (1984) demonstrates that teachers' interpretations of their subject matter and of available software are critical to understanding how microcomputers are utilized and thus what their impact is likely to be on both teaching and learning. Specifically, they discuss the results of a field test of a computerized simulation game the manifest context of which concerns rescuing a whale trapped in a fishing net. Some teachers interpreted the software much as its designers had and utilized it to supplement their teaching of concepts such as degrees, angles and vectors.

Others saw the software as a game about boats and navigation and limited its use to free periods or after school hours.

The preceding discussion suggests that study of microcomputers in schools needs to keep in mind that microcomputer utilization can be conceptualized as a dependent as well as an independent variable. On the one hand, a whole variety of factors influence whether and how these resources will be utilized. On the other hand, utilization is likely to have consequences which we need to understand. In either case one caveat is vitally important. Microcomputer usage in and of itself is hardly a unitary conceptually satisfying variable. Factors such as the purposes for which the computers are used (drill and practice, simulations, tutoring, etc.), the specific software chosen to achieve these ends, the ratio of students to microcomputers, and the physical location of the computers (classrooms vs. school libraries, etc.) all seem likely to influence how teachers and others respond to the new technology and how the technology influences teachers and schools in turn.

There are of course some obvious trade offs in using the ethnographic approach. The advantages of using this approach to study the particular issues studied here must be balanced against some disadvantages such as the folly of assuming that the important issues at one site are necessarily those at others and the large degree of subjectivity inherent in many aspects of qualitative research. Suffice it to say, since this is not a methodological treatise and such issues have been discussed in detail elsewhere (e.g., Campbell, 1979; Goetz & LeCompte, 1984; Guba & Lincoln, 1982; Reichardt & Cook, 1979; Schofield, in press) that in this particular case from our perspective the advantages far outweighed the disadvantages.

The Research Site

Data gathering took place during a two year period (1985-1987) in a large high school located in an urban setting. The school, which will be called Whitmore High School, serves approximately 1300 students from very varied socioeconomic backgrounds. Approximately 55% of the students are black, 40% are white, and 5% are from other, primarily Oriental, ethnic groups.

The school's faculty is about 80% white, and roughly 55% male. The gender composition of different departments varies dramatically in ways that one might expect given traditional sex roles. For example, about 70% of the mathematics teachers are men compared to about 30% of the English teachers.

The school chosen as the research site had computers available for instruction in varied areas such as computer science and business courses as is common these days. However, it also had a small set of very sophisticated computers available for the field testing of an intelligent computer-based geometry tutor developed by John Anderson and Franklin Boyle at Carnegie-Mellon University. Thus, this site let us examine numerous common present-day kinds of computer-usage as well as their usage as intelligent tutors. Since in many areas of instruction intelligent tutors are close to becoming a practical reality from a technical and fiscal perspective, close attention to the field test of the computer-tutor seemed likely to yield information of use in understanding how such innovations are accepted and what impact they may have.

During the first year of the study, the school had three main locations in which computers were concentrated. One of these was the room in which 10 Xerox Dandy Tiger computers were located. These highly sophisticated and very expensive computers were loaned to the school by the developers of the intelligent system for tutoring

geometry proofs which was being field tested at the school. The second main concentration of computers was in the computer science lab which contained 11 Tandy 1000 microcomputers. The third concentration of computers was a group of 12 AppleIII's used by students in the school's gifted program. In the study's second year, the business classes which had formerly had only a small number of computers received about 20 new ones. There were also a small number of other classes with one or two computers.

Research Methods

The two major methods of data-gathering employed in this study were intensive and extensive classroom observation and repeated extended interviews with students and teachers. Administrators were also interviewed when appropriate. Classroom observers used the "full field note" method of data collection (Olson, 1976) which involves taking extensive handwritten notes during the events being observed. Shortly thereafter, these notes are dictated into a tape recorder and then transcribed. Observers made the field notes as factual and as concretely descriptive as possible to help avoid unwarranted inferences.

One clear problem with the use of such notes as a data base is what Smith and Geoffrey (1988) have termed the "two-realities problem"-- the fact that the notes as recorded cannot possibly include literally everything that has actually transpired. Hence, a source of potential bias is the possibility of selective recording of certain types of events. Although this problem is impossible to surmount completely in qualitative observation, there are some steps that can be taken to minimize its negative effect. For example, we found it useful to have two researchers observe a single setting. Discussion of differences between the two observers' notes helped to point out individual biases and

preconceptions. Another technique useful in reducing the effect of such biases is actively to seek out data that undercut one's developing assessment of a situation. These techniques plus a number of others discussed in recent books on qualitative research in educational settings (Bogdan & Biklen, 1982; Goetz & LeCompte, 1984) were employed to reduce the "two realities problem." Fuller discussion of methodological details can be found in Schofield (1985).

During both years of the study, weekly observations were made in four geometry classes taught by Mr. Adams (a pseudonym, as are all names used in this paper). These classes, of varying ability levels, all utilized the computer-tutor developed by Anderson and Boyle (1985) to work geometry proofs. Since the tutors were not introduced until January of the study's first year, we were able to do a complete semester of observations in Mr. Adams' classes before the computer-tutors were available. As an additional source of comparative data, we also made weekly observations in the classes of the two other teachers who taught geometry at Whitmore High but who did not utilize the tutor. One of these teachers occasionally used the computer lab set aside for gifted students with his class of gifted students, as did Mr. Adams before the arrival of the more powerful machines in his room. In the study's second year, another teacher, Mr. Brice, used the computer-tutor with one additional class of students. Both this class and another geometry class of Mr. Brice's, which was taught using traditional methods, were observed weekly. The classes using the computer-tutor ranged markedly in size. Some were small enough so that each student had his or her own computer to work on. In others, students worked in pairs on the ten available machines.

To date, we have observed roughly 250 hours of instruction in the classes mentioned above, almost 100 of which involved classes actually using the computer-

tutors. The observation described so far allows comparisons (a) across different time periods within individual classrooms utilizing computer-based instruction, (b) between different ones of these classes, (c) between classes taught in the first year of the project and the second when the teacher was more familiar with the tutor, and (d) between classes utilizing the computer-based tutor and those which do not.

We also observed regularly in almost all other sites at Whitmore High School in which computers were used regularly for instruction. The purpose of observing in these other settings was to shed light on the question of which problems and issues are connected with microcomputer usage per se and which are specific to utilizing the computer as an intelligent geometry tutor. Thus weekly observations were made in three or more different computer science classes. Similarly, weekly observations were made in the 'gifted' computer lab. Regular observations were also made in other classes, such as visual communications, office automation, and business practice in which computers were available. A total of roughly 250 hours of observation were conducted in the settings just described.

Observers, no matter how omnipresent or insightful, are at a great disadvantage if they do not test their emerging ideas through direct inquiry with those whom they are observing. Because interviews can be so useful in providing the participant's perspectives on events, both formal and informal interviews were the second major data-gathering technique utilized in the research. All students from each of the computer-tutor geometry classes were interviewed during both years of the study.¹ Each year the first interview occurred before the students began using the tutor and focused on the students' expectations for the tutor, their perceptions of their teacher, and the like. The second interview, conducted after the students finished using the tutors, concerned

students' reactions to the tutor and their observations on how using the tutors had changed their classes. The bulk of these interviews consisted of open-ended questions. A random sample of students from the traditional geometry classes was also interviewed twice in the study's first year. These students were asked questions about their classes and their teachers identical to the non-tutor questions asked of the computer-tutor students.

Both formal and informal interviews were conducted with Mr. Adams and Mr. Brice, the two teachers using the computer-tutors, throughout the course of the research. All formal teacher interviews were tape-recorded and transcribed, as were all student interviews. Additional interviews were conducted with other computer-using teachers such as those who supervised the "gifted" computer lab, the special education teacher, and computer science teachers. Finally, numerous interviews were conducted with teachers who had formal access to microcomputers but who decided not to use them.

Although observation and interviews were the primary data-gathering techniques utilized, other techniques were employed when appropriate. For example, archival material such as letters sent to parents about the computer-tutor, internal school memoranda and announcements, and copies of the student newspaper were carefully collected and analyzed.

BARRIERS TO THE UTILIZATION OF COMPUTER TECHNOLOGY IN INSTRUCTION

Lack of Clarity About Why and How Computers Should Be Used in Teaching

The first and most obvious finding of our study was that, with the exception of the field test of the computer-based geometry tutor and computer science classes, computers were rarely if ever used in the teaching of academic subjects at Whitmore. This situation can be exemplified by examination of the extent to which computers were used to teach math at Whitmore. Although Board level personnel spoke of a computer-based remedial mathematics CAI program in all high schools, no such program existed at Whitmore. Careful monitoring of the uses to which the various computer labs were put turned up no evidence of the utilization of computers in any math course other than geometry. Most geometry classes never used computers at all. The two exceptions to this were two 'gifted' classes, one taught by Mr. Adams and the other taught by another white male, Mr. Trowbridge. Mr. Adams took his class to the gifted lab several times in the fall before the computer-based tutor arrived. Mr. Trowbridge took his students two or three times during the course of the year. Similarly, the use of computers for instruction in other courses was, generally speaking, minimal to non-existent.

This lack of utilization of computers in instruction could not be attributed primarily to either lack of availability of machines or to teachers' unfamiliarity with them. The gifted lab with its 12 computers was, according to our best estimates, used about 15% of the time on an average school day. Although the computers in the computer science lab were more heavily utilized, the head of the math department which was formally responsible for instruction in computer science indicated that he would try

to make the lab available to other teachers if they wanted it. However, he reported that he was never asked to do so.

The contrast between the general failure to utilize computers in instruction and their intensive use in the field testing of the computer-based geometry tutor raised what to us is a fundamental issue--just why and how should computers be used in instruction? It makes little sense to bemoan the low level of utilization unless one has a clear idea of what the advantages of computer utilization might be. Anderson and his colleagues have outlined a clear rationale for utilizing intelligent computer-tutors. Specifically, they point out that the constant monitoring and structuring of students problem-solving attempts, the fact that the tutor works from a carefully developed set of ideal and "buggy" rules in guiding the student, and the immediate feedback all give the tutor the capability to provide important facilitators of learning which one teacher can not hope to provide for a typical class of students (Anderson, Boyle, & Yost, 1985). The field test at Whitmore was a two-pronged effort aimed both at improving the software and seeing if students using it learned more than those in control classes.

However, in general, teachers at Whitmore appeared to have little conception of what parts of the curriculum might best be taught using computers, and when and how they should be used for drill and practice, for simulations, for their graphic capabilities, or the like. Since software development is primarily a for-profit enterprise, it seems likely that most software manufacturers will tend to produce products which can be easily marketed as performing a specific function. However, it seems unlikely that either they or practicing teachers will have the time or motivation to take a more global look at the whole issue and to produce what one might think of as a model of the use of computers in various substantive domains which links the actual or potential

characteristics and capabilities of different kinds of computers to teachers' instructional methods and goals in widely differing fields such as language arts, biology, and mathematics.

Of course, some efforts have already been made along these lines. For example, Walker (1986) and others have given thought to how the various capabilities of the computer might be useful in teaching mathematics. Patrick Suppes has developed a computer-based curriculum spanning both the elementary and high school years. Other innovators like Seymour Papert and the group at the University of Illinois which developed PLATO have also developed computer languages or curricula out of a vision of the particular role computers can play in teaching. However, an enormous amount of conceptual and empirical work remains to be done. This work involves addressing fundamental problems of values, with questions such as "What do we want our children to learn?" While such questions are old, the answers may be new as we strive to prepare students to function in a world which is rapidly changing and ever more heavily influenced by the burgeoning of technology. For example, the consensus of those who have dealt with this issue recently appears to be that a major shift in the goals of mathematics teaching is needed--away from an emphasis on rote practice of calculation skills and towards an emphasis on problem-solving, estimation, and statistics to name just a few areas which have previously received relatively little attention in the usual mathematics curriculum (Committee on Research in Mathematics, Science and Technology Education, 1985; National Council of Teachers of Mathematics, 1980; Romberg, 1984; Willis, Thomas, & Hoppe, 1985).

Thus, we would argue that any effort to utilize computers in instruction needs to start with very real consideration of the issue of just what needs to be taught. On the

one hand this position seems so obvious that it appears almost ludicrous as a recommendation. However, in the rush to produce software for the millions of machines now placed in educational settings developers may slight this important issue by depending on traditional or "obvious" answers rather than seriously reexamining the question. Having addressed this basic issue of what should be taught, the next set of fundamental problems concerns what part of this material can be taught better with the assistance of computers than without them. Here, at least three sets of questions arise. The first deals, of course, with the issue of cost effectiveness. The second set of questions concerns those functions which computers may perform uniquely well. Here we need to inquire what special capabilities the computer has and whether these unique capabilities have an important role to play in education. Finally, attention needs to be paid to the side effects of computer usage on a broad range of organizational, social, economic and intellectual outcomes. A striking though perhaps frivolous example of just how unintended and unexpected various side effects can be is the fact that Mr. Adams, the teacher most heavily involved in the field test of the computer tutor, complained that using the tutors gave him sore legs. Although he was in good physical condition, the squatting he did when consulting with individual students seated at their computers involved muscles that lecturing at the blackboard clearly did not.

Let us assume that attention to the question of whether computers should be used in teaching a particular subject yields at least a qualified yes as an answer. Let us further assume, perhaps less safely, that attention to the related question of how computers should be used also yields answers that do not require a major revolution of school organization as we know it today, although it may require significant changes in teaching. We would argue that a fundamental barrier to computer usage may still

persist -- specifically that in many cases at this moment in time the disincentives to computer usage outweigh the incentives for a great many teachers. Our goal in the next several sections of this paper is to outline barriers and incentives which appeared to influence utilization most importantly at Whitmore.

Lack of Familiarity with Computers

Several of the mathematics faculty at Whitmore doubled as computer science teachers and hence were quite familiar with such machines. However, for those teachers and administrators who were not familiar with computers, this situation posed a major barrier to utilization. For example, the coordinator for the gifted program who was in a good position to encourage teachers and students to use the Apple II's in the gifted lab, which generally sat idle except at lunch when students used them primarily for educational games and word processing, expressed his frustration at not knowing much about computers and not being able to find good ways to change that situation.

Sometimes I sit down with a beer in one hand and a manual in the other, but its pretty complicated to learn.... It just takes so much time to learn.... and I don't to to have it.

One issue which was frequently coupled with comments about lack of knowledge about computers was a sense that trying to use them exposed one to potentially embarrassing situations which undermined one's sense of competence. For example, Mr. Trowbridge who indicated that he found it hard to "get the hang of computers" argued that because of their youth students could pick up on computers quickly. Thus, by attempting to use computers with his class he reversed the usual situation in which he was more in command of the knowledge needed to perform well in class than were students. Ms. Prentiss who supervised the use of the gifted computer lab during lunch

periods clearly experienced a similar feeling of bewilderment and threat when first confronted by hardware and software problems which she had no training to handle.

I've changed! You know that... I'm getting a lot better at it... My husband taught me phrases like "Hmmm, looks like there's a bug in the program." I always assumed it was MY fault at the beginning. And then... I realized it's not my fault. It's inherent in the system's hardware and software.... It's not because I'm a nincompoop. Learning that... made a huge difference!!! Everything else falls into place if I can hold on to that!

Mr. Miller, the coordinator of the gifted program who was mentioned above, described this situation vividly in a conversation with a member of our research team, only this time the sense of lesser competence was felt in relation to a colleague.

Mr. Miller next came back to his comments about Mr. East (a science teacher who is the school's foremost "hacker"). He said "He's a computer whiz. He's way over my head... A couple of times I've asked him to explain things to me, but it gets so complicated. He goes on and on and I just sit there and say "I gotcha... I got it. I understand." But I don't understand a thing!

The necessity for having someone on the spot who is familiar with both the hardware and software in use was obvious in both the geometry computer-tutor lab and in the gifted computer lab. In the former situation it took two or three adults to keep things running fairly smoothly, and even this level of staffing was sometimes not adequate to the task. This extraordinary level of staffing was clearly connected to the fact that the software utilized was still being developed and refined. But observation of the gifted lab suggested that a wide range of expertise was necessary to keep things running smoothly, even with fairly simple machines and widely used commercially developed software.

Ms. Prentiss, who volunteered to supervise the lab as a "duty period" after having seen her husband accomplish a lot on their personal computer at home, had no formal training relating to computers except for a two-hour school system sponsored workshop a few years previously. After the first semester she convinced Mr. East, one of the school's few real "hackers", to assist her for part of the lunch period. Even with two adults doing their very best, the 6 to 12 students who usually came could not count on having machines and software operating smoothly as the following excerpt from our field notes indicates.

The students ... continue to have a lot of very nitty-gritty problems. Kathy can't get the printer going.... She's scowling and says in an annoyed tone of voice, "Please help me." Mr. East suggests several things, and after they try out 4 or 5 different approaches they finally get the paper to print out. Ms. Prentiss has been working with Sharon on word processing... For the last 10 minutes cries like, "I don't believe it" and "Oh, no. Not again!" have been emanating from both of them... Finally Ms. Prentiss calls Mr. East over... Sharon is clearly getting anxious, pacing around, picking her nails and the like. She takes her disc and inserts it in another computer hooked up to a different printer. She can't get this printer to work.... Ms. Prentiss rushes over to try to fix it saying, "I just don't believe it!!" Ms. Prentiss comes over to me (the observer) and says "I feel like quitting this..." At this point Mark calls to Ms. Prentiss "I need help..." Ms. Prentiss puts her head down on the desk briefly. She looks at me with what appears to be a mixture of mock and real despair and trudges over to Mark. (Later in the same period) Dan is trying to use a printer which Mr. East thought he had fixed. Dan's essay comes out quadruple

spaced. In addition, every single word is underlined. Ms. Prentiss looks at it and breaks into almost hysterical laughter. Dan looks annoyed. Ms. Prentiss says "I'm sorry, this is just too much -- too, too much!..." Mr. Adams and Mr. East are still working on the second malfunctioning printer. Mr. Adams says, "You know I have a trick. What I do with my Radio Shack computer is just to turn it on its side and hit it. Maybe that will work here..." They turn it on its side and give it a whack as one of them holds the tension on the paper feed. The machine begins to work.

The knowledge needed to make minor hardware repairs, to be able to distinguish which problems one can fix and which require outside help, and to operate specific pieces of software is only part of what is needed to utilize computers effectively in teaching. Equally or even more crucial is knowledge about the software available in one's subject area. At least two separate issues arose in this regard at Whitmore. First, teachers need to have a mechanism available for locating software which suits their needs. Secondly, they need some way to evaluate it. Although a few teachers like Mr. East were well aware of various information sources about educational software most teachers were not. Furthermore since the level of information available was so low, teachers were frequently, even generally, disappointed in the software they did get. Thus a vicious circle occurred with teachers believing that little good quality software was available, deciding to take a chance and order something, and then having their low expectations confirmed.

"Overload" of Knowledgeable Teachers

Becker's (1984) work suggests that individual teachers very often play a major role in providing the impetus for a school's obtaining instructional computers. Although

Becker reports a trend for administrators to become more involved in this process than was the case in earlier years, individual teachers still play a crucial role in the implementation stage with regard to issues such as deciding what software will be purchased and providing informal training for other teachers.

Such was certainly the case at Whitmore. For example, from all reports if Ms. Prentiss had not volunteered to supervise the gifted computer lab at lunchtime as her "duty" period instead of monitoring the halls, the gifted computer lab would not have been used on a daily basis. However, observations and interviews at Whitmore revealed a fundamental problem -- few teachers had any substantial knowledge about computers and no formal mechanisms were available for helping interested teachers utilize computer facilities. Thus increased usage of computers within the school meant increased burdens on teachers like Mr. Adams, Mr. East, and Ms. Prentiss. Yet aside from giving Ms. Prentiss "credit" for a duty period, no formal arrangement was ever made to respond to this situation. This put knowledgeable teachers in a position of conflict when colleagues or students requested help because that help had to be taken from time that was either their own personal time or from parts of the day which were officially allocated to other more traditional uses, namely teaching or preparing to teach.

Interviewer: What are the one or two major impediments to greater usage of the computers?

Ms. Prentiss: The time for some ONE person to coordinate the use of the room.... What I didn't realize when we started is that a teacher who doesn't have complete control of the class.... and know everything about the machines... could cause so much damage. They walk out of the room and who's got to deal with it? You know who... It's selfish, but I didn't bargain

to... I often give 2 periods a day and lots of extra time... ...What happened one time that other teacher asked (to use the room) I had to teach her class -- make up the dittos (about using the computers). Hey, I don't want word to get out I'm doing this. Then every.... teacher....

Thus present organizational arrangements stand in the way of optimizing computer utilization. New ways of meeting the lack of knowledge problem previously discussed must be found that do not place too heavy a burden on the teachers who have some interest and expertise. A number of potential solutions are quite obvious and involve familiar mechanisms, such a release time for knowledgeable teachers. However, both thought and research need to be devoted to exploring whether more imaginative solutions might be more effective and to delineating the consequences of the various possible solutions to this problem.

Attitudinal Barriers

As discussed above, a widespread lack of knowledge about computers appears to be a major impediment to their utilization. Yet supplying such knowledge will serve as an effective remedy to this problem only if teachers want to use computers in their work so that they take advantage of an environment which facilitates this desire. Such may not be the case.

At Whitmore there was evidence of many teachers' indifference to or even resistance to the idea of using computers in their teaching. One reasonable indicator of teachers' enthusiasm for computers is their level of interest in utilizing them or in learning about how to utilize them. Both appeared quite low as the following excerpts from interviews with Ms. Prentiss and Mr. Carter, a member of the math department, suggest:

Interviewer: How have other teachers responded to your efforts to make computers available (by opening the gifted computer lab at lunchtime)?

Ms. Prentiss: Generally surprise. I'm a bit of an anomaly. Not that many women do these things and... just "Why?" "Why?" It's one thing if you can do your own work on it, but why would you (do the extra work)? ... I've never been so isolated from teachers as I have this year. I don't even eat with them... So they... think I'm weird because I want to socialize with kids.

Interviewer: Have you had a chance to see the (geometry) computer tutor which Mr. Adams and Mr. Brice .. (are using)?

Mr. Carter: Yeah, but I'm not too fond with computers. I don't want any parts (sic) with computers. I'm the old-fashioned type. I don't want to learn anything new. Maybe that's my fault. I should go into learning computers. I had enough of computer training at Waterford University, but I don't know. I just -- after so many years, you build up a file on your subjects... For me to go into teaching computers... I would have to start all over. I would have to actually sit down and work everything out, and it would require a lot more work on my part to run a class the way I want it run. At this point in time I suppose everybody gets lazy and ... I just don't want to do it... I'm doing what I'm doing. Don't want to change.

We have already discussed one possible source of the teachers' general lack of interest in computers -- the threat that the process of learning to use them poses to teachers' sense of competence. Another related possible source of this attitude is the perception that computers pose a threat to the teachers' autonomy and to predictability

in teaching. Specifically, the possibility of "bugs" in the software or of hardware failures means the teacher may need outside assistance. In addition, a teacher using computers can not be assured of being able to have students cover the material planned for a specific day. An excerpt from our field notes illustrates this problem.

Peter can't get his computer started properly. He looks around and calls out "Miss" to Ms. Lee, a staff member on the computer-tutor project. She doesn't hear him. He twists all the way around in his chair and calls out quietly, "Somebody," but nobody replies. (Mr. Adams and both of the computer-tutor staff members are working with other students). Peter looks at me and rolls his eyes with an exasperated expression on his face. He sits passively for a while...(then) he calls out, "Excuse me, help!" Ms. Lee... goes over to him. (Peter works independently for about 15 minutes after getting started 10 minutes or so after most students). Towards the end of class, when Peter gets up and puts on his jacket, I say to him, "How's it going?" He replies, "The hardware is broken... On the first day we couldn't get it on. Yesterday it wouldn't let me off, and today, it broke!" (Later) I asked Ms. Lee what the problem was. She replied "The computer just froze out..."

One of the computer-tutor staff remarked during an interview

We found the machines behaved wonderfully (in our lab)... We get them in the schools and we were getting some really strange errors... It effected the atmosphere and the kids... There was A LOT of machine breakdown in school which frustrated me and it frustrated Mr. Adams and it frustrated the kids. And the worst problem was, they weren't the kind of breakdowns that you could duplicate. The Xerox man would come and run diagnostics (and not be able to find the problem)... It was real tough.

Of course, one would expect an unusually high incidence of such problems during the field testing of new software, but his kind of problem was by no means unique to the field test site as indicated by the field notes on page 17. This concern about the unpredictability of computers and the problems that this may pose for teachers may well have been reinforced by that fact that Whitmore, like many schools, was in a transition period between using manual and computerized means for a variety of clerical and administrative functions, most especially recording and reporting grades. This transition was far from smooth and it created a great deal of extra work and annoyance for the teachers. In fact, as a consequence of problems with the new computerized system teachers had to turn in their grades a week earlier than usual and the beginning of summer school was delayed so that marginal students could learn whether they had failed a class before the beginning of summer classes. Such a context was hardly conducive to encouraging teachers to use computers in their classes.

A final factor which seemed to contribute to resistance to utilizing computers was concern about the cost of the machines coupled with a fear that they might somehow be used to replace teachers. Such a concern is hardly surprising, especially with regard to the "intelligent" geometry tutor. Certainly those involved with the development of that software could foresee a day when the tutor could perform many if not most of a teacher's academic functions.

Interviewer: Do you think the tutor could be developed to the point where it and the student will form a self-sufficient teaching and learning unit?

Mr. Law (a member of the computer-tutor development team): I can foresee that....You wouldn't necessarily need a human. It's not a particular goal right now, but it's certainly a very viable possibility.

Because they were well aware that the idea of replacing teachers was an extremely volatile issue, the computer-tutor staff took great pains to emphasize that the tutor's goal was to help teachers not to replace them. However, some teachers found this hard to believe, or at the very least questioned whether expending such sums on a teaching tool made sense. The 10 machines utilized in the field test of the computer-tutor cost a total of nearly half a million dollars. Teachers used to using thirty dollar text books and pieces of chalk as teaching tools not surprisingly wondered at the cost effectiveness of this approach. Few were aware that by the end of the field test period the tutor was able to operate on the Apple MacIntosh rather than the \$50,000 Dandy Tigers which were used in the field test.

Logistical and Practical Impediments to Computer Usage

Becker's (1986) research shows quite clearly that computers tend to be utilized more when they are grouped in laboratories than when they are spread around in individual classrooms. Thus it is far from unusual to see recommendations that computers be grouped in this way. We would suggest that considerably more thought needs to be given to the question of how computers should be distributed and what the consequences of these various arrangements are. Our research suggested that somewhat different barriers to usage were associated with these two different arrangements. Specifically, when one or just a few computers were available to a class serious organizational and management issues arose, which teachers often just avoided by failing to use the machines. In fact, the computers in the gifted lab had originally been given to individual teachers for classroom use. However, when it became clear that the machines were not being used, indeed some machines had reportedly never even been turned on during their first year at Whitmore, they were collected into a central location.

The existence of a laboratory created its own problems which inhibited usage. First, teachers are very attached to their classrooms -- the arena in which they have the most power and autonomy (Lortie, 1975, Schofield, 1982). Utilizing a lab generally requires some coordination, thus again undermining a teacher's autonomy. Security arrangements, although necessary, heighten barriers by requiring greater coordination and emphasizing that the room is not the teacher's own. Using a lab takes the teacher off his or her "turf." This sense of going to foreign territory is well-illustrated by the fact that one teacher spontaneously likened taking his class to the computer lab to "taking a field trip inside the school." Finally, it is at least possible that grouping rather than dispersing computers undercuts involvement by removing the machines from most teachers' presence. While it is clear that many teachers let computers sit idle in their rooms, it seems at least possible that others would be encouraged by the easy availability of the resource to consider its possibilities.

Barriers to Recruiting and Retaining Qualified Computer-Using Teachers

Although in many fields there currently appears to be a sufficient supply of individuals interested in teaching, we are facing a shortage of well-qualified mathematics teachers. In fact in 1981 over forty states reported a shortage of such teachers (Romberg, 1984). The reasons for this situation are numerous and beyond the scope of this paper. However, we would suggest that many of those very forces which lead to the present shortage of mathematics teachers will operate even more strongly on teachers with strong computer skills. For example, pay differentials are often cited as one reason why teachers leave the classroom. Under most present systems of remuneration, classroom teachers with computer skills are paid no more than those without. Yet such skills are clearly a valuable commodity in the labor market. Thus teachers with such skills may

leave teaching in greater numbers or get so involved in after-hours consulting activities that their attention is diverted from their primary job. Although most teachers want to be treated as professionals, their job is not accorded a great deal of status. In sharp contrast, the mystique in our society which surrounds technology lends glamour and status to many, though far from all, computer-related jobs. Thus, those teachers with especially well-developed computer skills may find it more rewarding to adopt a professional identity relating to computers rather than to teaching. This phenomenon is illustrated by field notes on a conversation between a teacher at Whitmore and a member of our research team. The teacher, who was a member of Whitmore's science faculty, usually taught one section of introductory computer science.

Mr. Davidson then mentioned (to an observer) that he does a lot of outside consulting on computers. Recently when he was talking with a banker, the banker asked what Mr. Davidson's occupation was. Mr. Davidson replied, "I'm in computers." The banker asked if he was a programmer and Mr. Davidson said he replied, "No, I'm a consultant and a teacher." Mr. Davidson then went on to talk about how he had helped this banker to learn to use a personal computer saying, "I think I have a new client!"

Student Characteristics Which Can Serve As Barriers

At Whitmore certain kinds of students had the opportunity to use computers much more than others. Those students with the most actual or potential exposure to computers were, generally speaking, those from more privileged backgrounds. Their right to access was based on academic achievement rather than on background per se. But since the two were substantially related, the end result was that those from homes of higher socio-economic status had the most opportunity for computer use.

Recall that aside from the computers used in the field test of the geometry tutors, in the study's first year the only two large groups of computers in the school were in the computer science lab and a lab reserved for the use of individuals in the school's program for gifted students. Students in the gifted program typically came from homes in which one or more parents was employed in professions such as medicine or law or worked in well-paying managerial or executive positions. Since the school served a very varied student body, a substantial proportion of which qualified for free or reduced price school lunches on the basis of family income, the gifted students were clearly well above average in terms of socio-economic background.

Although the gifted students had the right of access to a special room full of computers, the actual usage was quite low since most of their teachers choose not to take their classes there. On the other hand, gifted students who were particularly interested in using the computers were able to do so at lunch time due to Ms. Prentiss' initiative.

The computer science classes were to a lesser extent also the preserve of the higher achievers since they were not available to the large number of students at Whitmore who were not college bound. Because computer science classes were in great demand some decision-rule had to be formulated for admitting students to them. In general, students who had not taken and passed introductory algebra were not admitted to the introductory course in computer science. Since general math courses were available as an alternative to algebra for students not heading to college, these students usually were not in a position to enroll in computer science.

In the study's second year, Whitmore's business program, which was heavily oriented toward preparing students for secretarial positions, received about 20 personal computers for use in instruction. Thus, this was the one context in which students in the non-college program had any substantial amount of contact with computers.

It is of interest to note that not only the amount of potential computer use but the kind varied markedly for the gifted, the regular college bound, and the non-college bound students. The gifted theoretically could enroll in any of the "computer using" courses, but the one reserved for them exclusively was the situation in which the students had a tremendous amount of autonomy with regard to what they would do and when and how they would do it. Specifically, those students could decide on a daily basis whether or not they felt like using the computers. Then, if they decided to use them, they were free to engage in activities varying from reviewing for SAT's to playing educational games. The computer science classes, open to the top two groups, were certainly more structured than this in that students had specific assignments. Yet students were given considerable leeway in how they fulfilled those assignments. For example, they might be asked to create a program, any program they wished, that contained a loop in its structure. In sharp contrast, students using the computers in the business classes not only worked on different content but in a much less autonomous way. Typical activities were to do drill and practice on the computers on topics such as filling rules or to type textual material from their workbooks.

The point of the above discussion is two-fold. First, moderate or low academic achievement served at Whitmore as a barrier to computer usage. Since academic achievement and social class were clearly correlated at Whitmore, as they are more generally, students from relatively low socio-economic backgrounds tended to face barriers to computer usage which their more privileged peers did not. Secondly, the kinds of skills learned on the computer and the social contexts in which they were learned differed dramatically for students of different social backgrounds.

The preceding discussion of the way in which a student's personal characteristics

can serve as a barrier or facilitator of computer usage has ignored two other potentially important characteristics -- gender and race. At Whitmore there were clear indications that gender served as a barrier to computer usage to females. There was some, but less strong and obvious ways, in which race appeared too as well. However, since analysis of the data on these two issues is far from complete, no further discussion of them appears appropriate in this particular paper.

MOTIVATORS OF UTILIZATION

Many forces such as those outlined earlier conspire to keep teachers from using computers in instruction. It seems logical to argue that two things need to occur before the situation changes markedly. First, we need to learn how to overcome these barriers. Secondly, we need to learn more about incentives to usage, for even in the absence of major barriers change seems very unlikely to occur without the presence of positive forces leading to it.

At Whitmore High School, three major factors seemed to lie behind the acquisition and utilization of microcomputers. First, there were the relatively rare cases in which a teacher saw some real very positive instructional purpose to using computers and made a major investment of time and energy so that students could benefit from them. The two clearest cases of this were Mr. Adams, who was very enthusiastic about the possible benefits of the computer-tutor, and Mr. Edwards who taught special education classes. The latter teacher actually wrote two small grant proposals to acquire money for a modest computer set up for his classroom.

Second, some teachers, notably Mr. Adams and Mr. East, just plain enjoyed computers. Their own personal enthusiasm for the machines seemed to spill over into a desire to help students learn about them. Although overall their influence was extremely

constructive, there did appear to be some disadvantages to having a high proportion of the teachers (outside of computer science) who used computers being motivated by the sheer love of "hacking." First, as indicated earlier, there was such a gulf in knowledge between people like Mr. East and the rest of the faculty that others sometimes felt intimidated to ask for or unable to understand the information they sought. Secondly, student-teacher interactions ostensibly designed to teach specific substantive material using computers sometimes got transformed into information sessions on hardware, computer programming, or the like—topics which these teachers found extremely interesting. This transformation did not occur when Mr. Adams used the computer-based geometry tutor with his class but was evident in some of his trips to the gifted computer lab with the same geometry classes. The extent to which this transformation was a disadvantage depends, of course, on one's assessment of the relative value of such information and of the work which students would have been doing otherwise. Sometimes the discussions of computer programming seemed to be valuable educational experiences. However, at least as frequently discussions focused on issues which in our judgment were of rather ephemeral value, such as the prices of various computer set ups and where certain pieces of game software could be obtained.

A third very obvious motivation for the acquisition of computers at Whitmore was a desire to impress the public, especially parents of school age children. Mr. East candidly discussed the situation in an interview:

It's (having a computer lab) something you can brag about to parents... We're in direct competition with private schools and Mr. Miller, the vice-principals, and the counselors romance the parents at the beginning of ninth grade. "You sure want to send your students here... Let me show you what's going on..."

They (visit) the room downstairs showing them the marvelous new machines... which many private schools simply cannot afford.

Interestingly, access to computers was also seen as a badge of status by many within the school. Although the special education teacher used his computer to very good effect, he also felt it served a valuable public relations function for him and his students within the school.

It's a motivational thing if nothing else for me to have it in a special ed class so that mainstream kids passing by as well as colleagues (see it). There's still a mystique about it... They think you're some kind of whiz... and all you're doing is punching out stupid discs... It gives you a little ego trip. Your colleagues recognize that you're doing something innovative...

Unfortunately to the extent that public relations is a motivation for acquiring computers, the machines serve their purpose at least tolerably well sitting unused. Thus while public relations concerns help to place computers in the school they do not necessarily lead to constructive use of the machines.

THE IMPACT OF COMPUTER USAGE ON CLASSROOM FUNCTIONING

The major part of this paper has been devoted to discussing factors which appeared to inhibit computer usage for instructional purposes. However, a second major class of issues connected to the utilization of computers for instructional purposes is the impact that computers have on teaching. Although a relatively small amount of research has been done on this topic, there is evidence that the impact of computers is less consistent than one might expect - that rather than shaping the classroom in highly predictable and clear-cut ways, computer usage is shaped by the context in which it occurs (Sheingold, Kane, & Endrewit, 1983). It seems clear that there is no necessary

set of consequences that follow from computer usage, since these machines can be used in so many different ways and to such different ends. Yet our observations of the computer based geometry tutor at Whitmore suggested that teachers must deal with a number of important issues when using computer based instruction. How each of these issues is handled may ultimately determine whether and how classrooms are influenced by computer usage. Our goal here is not to be comprehensive. Rather we would like to suggest the areas in which our analyses to date suggest change with important educational implications may occur. It is important to point out that such changes can occur as unintended side effects of computer usage as well as consciously planned adjustments to the new instructional technology. The changes discussed will be drawn from contrasting computer-tutor classrooms with other geometry classes taught by the same teachers since this is the situation which provides the most unambiguous evidence with regard to the issue of computer usage and classroom change.

Change from "Whole Group" to "Individualized Instruction"

One of the more obvious changes which often accompanies usage of any substantial number of computers in a classroom is a shift from whole group to individualized or at least small group instructional techniques. Such a change quite clearly calls on different skills in a teacher. For example, in the high school setting one's prowess as a lecturer becomes less important while one's ability to respond effectively to individuals becomes more crucial. Thus, for example, when using the computer-tutors, Mr. Adams dropped almost entirely his practice of devoting the opening portion of his class to a lecture. Instead students were instructed to go directly to their machines and to get started individually as Mr. Adams circulated among them helping out as problems arose. However, a great many less obvious but potentially important consequences computer usage for classroom structure and functioning were apparent at Whitmore.

Changes in Amount and Type of Attention Given to Students at Varying Achievement Levels

Although students using the computer-tutor were tracked into classes of three different ability levels, there was still considerable heterogeneity within classes, especially in regular classes. Mr. Adams was, of course, very aware of these differences. His clear tendency when working problems at the blackboard in whole class instruction was to call on the more advanced students as previous research has suggested is often the case (Bossert, 1979). This both raised the probability of a correct answer and saved considerable time. In addition, it saved the slower students embarrassment as can be seen in the following excerpt from our field notes. It also meant that they received less attention from Mr. Adams and often had the answers provided before completing a problem successfully.

Iris (one of the better students) says heatedly, "That's unfair. You always call on Tom for extra credit!..." Mr. Adams doesn't answer her complaint directly. Instead he assigns another problem and says, "Iris will choose who answers this time. This is extra credit." Annie and Peter finish first. They have their hands up. Mr. Adams says, "Okay. Choose." Iris says, "You put your hands down. I want to call on one of those. (She points to where Darlene and Kit, who are clearly the slowest students in this class, are seated). Both girls have their heads bent over their papers, still working. Darlene says to Mr. Adams, "Can I ask a question?" Mr. Adams goes over to where she is working and answers it. She continues to work. Iris says, "Are you ready Kit?" Mr. Adams says, "The bell is going to ring any minute and no one will get credit." He continues sarcastically, "You'd be a good teacher. It's your class. Time is going." Iris goes up to the front of the room. Mr. Adams, in a voice close to

a shout, says, "WOULD YOU PLEASE CALL ON SOMEONE!"... Iris hesitates and then calls on Darlene. Darlene gives 7 angles correctly but gets the 8th one wrong. Peter volunteers the correct answer and Mr. Adams lets him show how he got the answer. He says, "This is the one you all missed so I want you to watch it..." (The bell rings). Iris says to Mr. Adams, "Sometimes it's not having the right (answer) -- it's having a chance. If you give them a chance...." Mr. Adams interrupts heatedly, "Here are people having difficulty. You... focus all of the attention on them. Isn't that embarrassing? It puts them in a corner." Iris counters, "Okay, okay, but why don't you ever call on them?" Mr. Adams replies, "You need to learn something about people. They get it wrong. They make bad subtraction errors. You're different. You know where it's at..."

When using the computer tutor, in contrast, the slower students often received considerably more attention than the brighter ones. In fact, it was not uncommon for the observer to estimate that Darlene and Kit received 4 or 5 times as much attention from Mr. Adams as did the more advanced students. Such attention was not likely to be embarrassing because students were often unaware of exactly with whom Mr. Adams was working. In addition, since students could proceed at their own pace, Mr. Adams' working with the slower students did not impede the rest of the students as much as under a more traditional whole class method of instruction. We do not claim that all teachers will respond as Mr. Adams did. However, since many teachers are concerned both with keeping a class learning and with avoiding student embarrassment it seems reasonable to speculate that they might react to the change in a similar way.

Changes in Traditional Evaluation Practices

The arrival of the computer tutors created a problem with regard to how to grade students. Before their arrival, Mr. Adams used a very traditional point grading system with a certain number of points allocated for homework, tests, and the like. However, since one of the major advantages of the computer-tutor was that it allowed students to proceed at their own pace, grading everyone according to the same standard of accomplishment no longer seemed so appropriate.

Interviewer: Has the introduction of the tutors changed the basis on which you assign grades?

Mr. Adams: THIS IS A PROBLEM!!! Oh my God, yes, how do I grade them?... I've had to develop a policy... (Let's say) when they came in and started on the tutor they had a grade of C. If they came in everyday and worked everyday and made a legitimate effort, they'd go up to a B.... A half-assed effort, they'd go down to a D. If they came and didn't give a damn at all they'd go down to an E...

Interviewer: So really effort is the main thing now.

Mr. Adams: ...Effort will mean a lot more... It had to. See, I'll be honest with you... I just don't buy effort. It doesn't mean much to me, it doesn't... A college is going to look at that grade... so I can't give a B for effort. The grade has got to reflect what they know. Let's face it, these things (tutors) are going to be here for one report period... It's not going to change their grade for the year by any real wild difference.

Interestingly, the chairman of the math department complained to our project staff that he could not evaluate Mr. Adams very well since the class was run so differently from

ordinary ones and different skills were needed. Thus the utilization of the tutor raised questions about teacher evaluation as well as about student evaluation.

There is no reason to assume that computer usage will automatically change grading practices. Yet research by others studying very different kinds of computer usage also suggests that using computer technology has important implications for assessment (Hawkins & Sheingold, 1986).

CONCLUSIONS

We would argue that further thought and research on computers and instruction needs to be grounded in a conception of why and how computers can be effectively used. Such a conception must be based on an analysis of both what students need to learn and the special capabilities and characteristics of computers. Since software differs so dramatically in purpose, scope, and content, researchers trying to understand computers' impact on teaching may find it necessary to employ a strategy like that utilized in the study discussed here -- that is, studying a particular kind or kinds of computer usage. Although in some ways such an approach is quite limiting, it has significant advantages as long as a wise choice is made about the kind of usage studied. Two important choice criteria, which are not necessarily correlated, are extensiveness of usage and instructional promise. Study of the former lets one assess what is happening while study of the latter lets one assess what could happen.

Usage of computers in teaching many subjects will require a substantial amount of change. Effective usage of these resources undoubtedly will require even more change. We have outlined a few of the important barriers to change suggested by our own research. Undoubtedly there are many others deserving of attention. Unless and until

barriers are reduced and incentives are increased there is little reason to think that computers will be utilized to anything like their full potential. Issues of barriers and incentives to change must be addressed at many levels -- economic, organizational, and psychological to name just a few. Research must not only isolate the most important barriers and incentives but also focus on how to change the present situation in which barriers to effective usage may well often outweigh incentives.

A focus on barriers and incentives implies an emphasis on utilization, specifically a desire to see greater utilization of computers in teaching. However, utilization, per se is a sterile, even potentially dangerous, goal. The reason for desiring utilization, increased learning of valued material, must be constantly kept in mind. Thus a second major focus for future research concerns the consequences, both intended and unintended, of computer usage. Reflection on the issues we have suggested as worthy of study here raises an important point. The mere study of outcomes is not sufficient. Rather we would suggest attention to the processes that mediate those outcomes. A focus on processes and mediating variable has two major advantages. First, it is more illuminating from a scientific perspective than straight in-put out-put research. Second, it is likely to be a much more fertile source of ideas on how best to equip teachers to handle the new demands and to take advantage of the new opportunities which computers present.

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FOOTNOTES

¹To be more precise, we asked all computer-tutor students and their parents to agree to the students participating in interviews. A similarly sized sample of control students were also invited to participate in the study. On the whole cooperation was excellent, with 90% of the computer-tutor students and 82% of the control students who were selected for interviews participating.