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ABSTRACT

This research was an exploratory study of which teachers, students, and teacher-student combinations benefit most from a particular aspect of computer-assisted instruction. The study is based on teacher and student evaluations of different teaching styles while using instructional software. Three teaching styles (monitoring, coordinating, and mediating) were used with each of three software packages in three fifth grade classes. The classroom teachers and 18 students, selected to represent differing preferred learning styles, were interviewed about the advantages and disadvantages of each style/software dyad. Contrary to expectations, the effectiveness of the three styles did not seem to depend on the primary instructional style of the teacher or on the preferred learning styles of the students. Rather, the results suggested that, for optimal effectiveness, all three styles should be used with every instructional software program. The mediating style provides a demonstration of the software, allows the teacher to highlight the important concepts, and shows the students what achievement is possible. Coordinated activities provide additional time and contexts for students to learn the concepts. The monitoring style allows students to work with the concepts at their own pace. Demonstrating these styles to teachers in their classes seemed very useful for encouraging them to use the styles themselves. (Contains 52 references.) (Author/KRN)

Teaching Styles and Instructional Software

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Abstract

Many studies have investigated whether or not computer-assisted-instruction is effective and how the effectiveness varies with certain aspects of the software, such as graphics, sound, and user control. Such research, however, has focused on results for whole groups of students. The environment for the use of computers — the impact of the teachers and students who use it — has been largely uninvestigated. While the question of, across *all* teachers, *all* students, and *all* teacher-student combinations, what aspects of software are effective has been addressed, there has been little research into for *which* teachers, for *which* students, and for *which* teacher-student combinations is a particular aspect of software use effective.

This research was an exploratory study based on teacher and student evaluations of different teaching styles while using instructional software. Three teaching styles (*monitoring*, *coordinating*, and *mediating*) were used with each of three software packages in three grade 5 classes. The classroom teachers and eighteen students, selected to represent differing preferred learning styles, were interviewed as to what they felt were the advantages and disadvantages of each style/software dyad.

Contrary to expectations, the effectiveness of the three styles did not seem to depend on the primary instructional style of the teacher or on the preferred learning styles of the students. Rather, these results suggest that, for optimal effectiveness, all three styles should be used with every instructional software program. The mediating style provides a demonstration of the software, allows the teacher to highlight the important concepts, and shows the students what achievement is possible. Coordinated activities provide additional time and contexts for students to learn the concepts. The monitoring style allows students to work with the concepts at their own pace. Demonstrating these styles to teachers in their classes seemed very useful for encouraging them to use the styles themselves.

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1 Research on Effective Instructional Software

Over the past few years, there has been a trend away from instruction about computers toward instruction with computers. Yet, as Becker (1987, p. ii) noted, "existing studies provide little guidance for schools to decide how to use computers for instruction", and even less guidance to teachers. Some educators argue for more and better teacher training. However, the problem may be more basic. While there has been research into what makes for more and less effective instructional software, there has been little research into what makes for more and less effective *uses* of instructional software.

Early research into the use of computers in education focused on the effectiveness of computer-assisted-instruction (CAI). The achievement of students who used CAI was based on some measure, usually involving a post-test, and was compared with that of students who did not use CAI. The results of such studies were mixed: some studies reported significant increases in achievement, some reported no significant increases, and some reported no significant increases but reduced time for the same achievement.

Perhaps because of the mixed results of those studies, researchers began to address what aspects of CAI made it more or less effective. Studies investigated the impact on achievement, again based on some measure, of the use of color, highlighting, sound, graphics, user control of pace, user control of sequence, and other aspects of the software.

Studies of the two types described above are very important. Before an innovation is introduced into mainstream education, the question, "Can this innovation be effective?" needs to be asked. If the answer is yes, it can be effective, research (formal and informal) is needed into what makes it effective, when it is effective, and what can make it more or less effective. Unfortunately, much of the research in computer use in education has focused on aspects of the software or logistics of its use and on results for whole groups of students. The environment for its use, the impact of the teachers and students who use it, has been largely uninvestigated. While the question of, across *all* teachers, *all* students, and *all* teacher-student combinations, what aspects of software are effective has been addressed, there has been little research into *for which* teachers, *for which* students, and *for which* teacher-student combinations is a particular teaching style while using instructional software effective, or which of a variety of styles is more or less effective.

1.1 Impact of the Teaching Style

As part of a study into the impact of teacher actions on student achievement, Bennett and Jordan (1975, 1976) developed a typology of teaching styles. They believed that dichotomous descriptions of teaching style were insufficient because a teaching style comprises *many* teaching strategies, not just one. It is in this sense, consisting of multiple teaching strategies, that *teaching style* is used in this paper.

Much research has been conducted into what acteristics and actions of teachers are effective in promoting student learning (cf. Borich, 1977; Rosenshine, 1983; Brophy, 1986; Rosenshine, 1986), but there has been little research into effective teaching styles while using instructional materials (Yarger and Harootunian, 1978; Brophy and Alleman, 1991). Classroom observations have found that instructional software is often used with no involvement from the teacher other than selecting the packages to be available and arranging for students to use them as they wish (*cf.* Mathinos and Woodward, 1987; Blackstock and Miller, 1988; Damianakis, 1989). Some teachers believe "the important thing is that they use them, not what they do," (Ragsdale, 1990, p. 2) and that "anything they do is better than not using the machine" (Mathinos and Woodward, 1987, p. 12; also Colgan, 1990). Some software, particularly early mainframe packages and more recent intelligent-computer-assisted-instruction packages, encourage the belief that the software provides the necessary introduction, practice, monitoring of progress, review, and remedial instruction (*cf.* Suppes, 1967/1980; Papert, 1980; Anderson, Boyle, Reiser, 1985; Tennyson, 1987). More recently, arguments have been made that teachers need to be an integral part of the activity when students use instructional software (Dockterman and Snyder, 1986; van Deusen and Donham, 1986–87; Blackstock and Miller, 1988; Bowers, 1988; Pogrow, 1988; Pogrow, 1990; Ryba and Anderson, 1990; DeVillar and Faltis, 1991). Unfortunately, research on effective classroom use of computers seems to largely ignore the impact of the actions of the teacher.

In one of the few studies in this area, Delclos and Kulewicz (1986) followed eight grade 6 students as they used a problem solving software package. The students used the program individually with a teacher present. The teacher, however, did not offer any assistance until a student had spent two consecutive 25-minute sessions without solving a problem. The researchers found that each student did reach a plateau and could not solve many of the problems (in most cases, more than half of the problems) without teacher intervention. They concluded that their study suggested that "attention to the mediational role of an instructor will continue to be critical" when students use problem solving software (p. 144).

Sherwood and Hasselbring (1986) investigated the effect of three different presentations of a science simulation on the achievement of 145 grade 6 students. The students were randomly assigned to one of three groups: (a) using the simulation in pairs on a computer, (b) using the simulation as a whole-class activity on a computer, and (c) using the simulation as a whole-class activity with the researcher assuming the role of the computer. In the immediate post-tests, males overall scored significantly higher than females overall. There was a trend toward group (b), whole-class activity on a computer, scoring higher than the other groups, but the difference was not statistically significant. On the post-tests six weeks later, females in group (b), whole-class on a computer, scored significantly higher than the males in that group while the males in group (a), pairs on a computer, scored significantly higher than the females in that group. However, there was no significant difference between the groups. According to the researchers, these results suggested that, in some circumstances, using a simulation for large group instruction is at least as beneficial and may be more beneficial than students using the simulation in pairs.

Gourgey (1987) investigated the effects of three different teaching styles when using CAI. Remedial instruction in reading was given to 77 grade 4–8 students and in mathematics to 124 grade 4–8 students in a total of six schools. In two schools, the students went to a computer teacher for *coordinated instruction* in the particular area; the students were with the computer teacher for the full class period, during which they received group instruction from the computer teacher based upon the content of the software and practiced the concepts with the software. In two other schools, students used the software in a *pullout with reinforcement* situation; students received regular instruction from their classroom teacher which was not necessarily matched to the content of the software and went to a different room to use the software with a computer teacher, who monitored their progress. For good weekly achievement and attendance, students were given praise and stars and, for exceptional achievement and completion of specific objectives, students were given prizes and certificates. In the remaining two schools, students used the software in a *pullout without reinforcement* environment; like the students in the *pullout with reinforcement* situation, these students received instruction from their regular teacher and went to another room with a computer teacher to use the software. However, with these students, the computer teacher did not monitor their progress with the software; they did not receive the praise, stars, prizes, or certificates. Gourgey found that, with reading, the students receiving reinforcement achieved significantly higher on the *Comprehensive Tests of Basic Skills* than either the coordinated instruction or non-reinforcement students. With the mathematics instruction, however, students in the coordinated instruction group achieved significantly higher than those in the other two groups. This research suggests not only that the level of involvement of the teacher when using software may impact the achievement of students, but also that there may be a involvement/software interaction effect.

1.2 Impact of the Primary Instructional Style

The effectiveness of classroom use of software probably depends not only upon the style with which it is used, but also upon how comfortable a teacher is with that style. In particular, while there are many advocates of integrating computer use into the curriculum, there may be a difference between integrating the software and making it "fit in". A teacher who prefers to use a lecture mode predominantly may have difficulty developing a unit around a software simulation whereas a teacher who prefers small group work predominantly may have difficulty using a software package as a whole group lesson.

For most teachers, using instructional software is innovative; it is a new curriculum material with which they have little, if any, experience. Therefore, using instructional software involves changes in their current practices. According to Fullan (1982), the three main criteria used by teachers in deciding whether or not to change their practices are the perceived benefits and costs to their students, the perceived benefits and costs to the teacher, and the clarity of the descriptions of the new practices. Thus, assuming all other aspects equal, the more similar a new practice is to an existing practice, the clearer the description will be to the teacher, the lower the costs will be to the teacher, and the more likely the teacher will be to try the new practice. Researchers have found that teachers often initially use software that is compatible with their current practices and in ways that are compatible with their current practices (Olson and Eaton, 1986; U.S. Congress, Office of Technology Assessment, 1988; Wiske and Zodhiates, 1988; Miller and Olson, in press; Tobin and Dawson, 1992), but not always (Rose, 1986).

Teachers often find, however, that available software is not fully compatible with their primary instructional styles. In such situations, a teacher must decide between not using a particular piece of software, modifying the software in some way to make it compatible with the instructional style, or modifying the teaching to make it compatible with the software. Modification of one's teaching style is often done on an experimental basis; there is uncertainty about the benefits and costs to students and teacher. The value of the modified practices are assessed through comparisons with prior practices to determine which practices are better. Such experimentation can be a catalyst for critical analysis and permanent modification of a teacher's primary teaching style (Olson and Eaton, 1986; U.S. Congress, Office of Technology Assessment, 1988; Olson, 1992) or it may lead to a rejection of the new practices and a return to the previous style. Thus, software use by a teacher may be classified as being compatible with current (possibly new) practices, as experimental, or as a tried and rejected use.

The effectiveness of software may vary with the category of use. If the teacher is comfortable with and confident of the teaching practices involved, the use of the software may have a positive effect. There may be few benefits to using the software, however, if the teacher is experimenting with new practices and is uncertain of the outcomes or has previously used similar practices and deemed them to have benefits too low or costs too high to permanently adopt them.

1.3 Impact of the Preferred Learning Style

While Sherwood and Hasselbring (1986) found no statistical differences overall between students using a computer-based simulation in pairs, the same simulation as a whole class, and essentially the same simulation as a whole class with the researcher acting as the computer, they did find statistically significant differences of achievement between males and females. One assumes that those results were not due to innate differences between males and females but were due to differences in how they related to the learning situation.

Dunn, Beaudry, and Klavas (1989) defined "learning style" as "a biologically and developmentally imposed set of personal characteristics that make the same teaching method effective for some and ineffective for others," (p. 50). A person's learning style includes, but is not limited to, preferences for learning with specific temperature, lighting, and noise conditions; with others or individually; through seeing, hearing, or manipulating; from an authority or by oneself; during certain hours of the day; while eating or not; and using inductive or deductive reasoning. Smith and Renzulli (1984) defined learning style as "the range of instructional strategies through which students typically pursue the act of learning," (p. 45). They contended that the teacher's job of addressing individual preferences was easier, and as effective, when the available information about students was in terms of preferred instructional strategies rather than in terms of psychological characteristics. Research has shown there can be increased student achievement when instruction is matched to learning style characteristics or preferred learning strategies (Smith and Renzulli, 1984; Dunn, Beaudry, and Klavas, 1989) and there are calls to utilize learning style information to match or adapt instruction to students (*cf.* Frase, Talbert, and Hetzel, 1984; Keefe, 1987; Bonham, 1989).

Teachers appear to use learning style information informally, if not formally. Comments such as, "Nothing else seemed to interest them, but that activity did", "We're not supposed to teach phonics anymore, but that's the only thing that gets through to some of these kids", and "It's great for some students, but it's too much for others; they get over-excited" are common. Indeed, it is almost expected that teachers will cover the same material with multiple presentations to "reach" as many students as possible. Yet, with the exceptions of gender, computer experience, and ability level, there seems to be little research into the impact of student characteristics on the effectiveness of software use.

In one such study, Rowland and Stuessy (1988) investigated the interaction of cognitive style and CAI format. Forty-five elementary education majors were classified as either wholist or serialist learners using the *Study Preference Questionnaire*, a Likert-type scale with which people indicate their preferences for proceeding from the general to the specific or from details to broader concepts. Students were randomly assigned to receive instruction on home energy through a computer simulation, deemed to be wholistic instruction, or a computer tutorial, deemed to be serialist instruction. After the instruction, students completed a concept web and an achievement test. Students for whom the instructional format matched their classified cognitive style scored significantly better on the achievement test than students with a mismatched format. While the difference in score on the concept web was not significant, there was a trend toward students receiving the matched format scoring higher.

2 Research Design and Implementation

Assuming that the teaching style used with instructional software and the learning styles of the students do influence the effectiveness of instruction, there is no one best way to use computers in education. Rather, what is best depends upon the teacher and the students. This research, reported more fully in Benaloh (1993), investigated the impact of three teaching styles, the primary instructional style of the teacher, the preferred learning style of the student, and the subject matter and type of software on what worked well as defined by teachers and students. The initial design of the study was that teachers would develop and implement lesson plans for the software use in consultation with this researcher and that this researcher would observe during the lessons. However, teachers were very hesitant to participate out of concern for how much time participation would require. The design was modified so that this researcher developed the lessons and taught the classes during the sessions while the teachers observed. With that modification, three grade 5 teachers in a rural, northeastern United States school district volunteered to participate in the study in the spring of 1991: Ms. Alcott, Mr. Boyd, and Ms. Reilly[1].

At the beginning of the study, the instructional styles of the teachers and the preferred learning styles of the students were assessed. There are many different definitions of learning styles and many different assessment instruments (*cf.* Dunn and DeBello, 1981), some of which focus on psychological aspects, some on environmental aspects, and some on instructional aspects. In this study, the *Learning Style Inventory* of Renzulli and Smith (1978) was used. Students rated, from very unpleasant to very pleasant, examples of nine different instructional activity categories: projects, simulation, drill-and-recitation, peer teaching, discussion, teaching games, independent study, programmed instruction, and lecture. Based on those self-reports of what types of learning activity categories were pleasant, 18 students were selected to be interviewed about each style/software dyad. The students were selected such that, for each of the nine activity categories of the *Learning Style Inventory*, one selected student rated that category as relatively highly pleasant and one selected student rated that category as relatively highly unpleasant.

Near the beginning of the study, each teacher was interviewed individually to ascertain the instructional strategies used by the teachers, their current use of software in their classrooms, their criteria for evaluating instructional activities, and to answer their questions about this study. The selected students were interviewed as to what classroom and computer activities they liked and disliked.

Each of three teaching styles was used once with each of three software packages in a randomized Latin Square design (see Table 1). Each style/software-package dyad was used for approximately two 40-minute periods per week for three weeks.

[1] All names are pseudonyms.

Class\Software	Package 1	Package 2	Package 3
Class 1	Style 1	Style 3	Style 2
Class 2	Style 2	Style 1	Style 3
Class 3	Style 3	Style 2	Style 1

With each class, each style and each software package will be used exactly once. Overall, each style and each package was used exactly three times.

Table 1: Latin Square Design: Class, Teaching Style, and Software Package

All but two of the sessions were videotaped and a journal was maintained by this researcher about what happened in each session. During the study, other instructional materials, including other software, were used without regard to the study.

At the beginning of each three-week session, students completed a pre-use activity to assess their current capabilities with the content matter. At the end of each three-week session, students completed a similar post-use activity. The teachers and selected students were then interviewed as to their reactions. The teachers were asked what they felt worked well and poorly for themselves and for their students, what changes they would suggest, and what they would recommend retaining. The students were asked their opinions of the software and the style, whether they would recommend the software to a friend, and whether they would recommend the software for classroom use. Both teachers and students were asked to indicate into which of the nine instructional activity categories from the *Learning Style Inventory* they would place the style/software dyad just used and why. Each category was listed on an index card with three specific examples taken from the *Learning Style Inventory*. At the end of the study, debriefing interviews were conducted to solicit further comments about and reactions to the software and styles. The interviews were audio-taped and then transcribed.

Throughout the study, classroom observations were conducted by this researcher to become familiar with the teachers, students, curricula, and routines.

2.1 The Teaching Styles, in Theory

When using instructional software, as with any instructional materials, a teacher must make many decisions about how students will use it. Among those decisions are whether students will be given free choice of which software to use or will be assigned a particular program; whether students will use the software throughout the whole day or during certain time periods; whether or not to formally schedule students so that everyone has equal or equitable opportunities to use the software; whether students will work individually, in small groups, or as a whole class; whether the teacher will address the whole class (as in a lecture format) or will address students individually as they need assistance; whether the software will be associated with other activities in the curriculum or will be isolated in the curriculum; and how much the teacher will track the progress of the students through the software.

For this study, the answers to the first three of those questions were fixed: students were told specifically which software to use, the study was conducted during fixed time periods, and all students had the opportunity to use the software during those time periods. The answers to the remaining questions were manipulated to define three teaching styles: *monitoring*, *coordinating*, and *mediating*. The monitoring style was defined as students working in groups of up to three, without associated curricular activities, and with the teacher addressing individual students as problems arose and maintaining records of the progress of students as they used the software. In the coordinating style, students would use the software as in the monitoring style (in groups of one to three and with individual teacher assistance), but there would be no formal records maintained of student progress and there would be associated curricular activities involving the same concepts as those of the software. The mediating style was defined as the software being used by the whole class at one time, with the teacher addressing the entire class, without associated curricular activities, and, by virtue of the lack of individual use of the software, no records would be maintained of individual student progress. These are styles of *using* the software, not of the software itself, as any piece of software can be used with any of the styles and the same software can be used with each of the styles. This is not an exhaustive list of possible styles, but represents some of the styles described in the literature (*e.g.*, Olson and Eaton, 1986; U.S. Congress, Office of Technology Assessment, 1988; Damianakis, 1989). Complete descriptions of the teaching can be found in Benaloh (1993).

2.2 The Software

Gourgey (1987) found that the most effective style of use with mathematics software was *not* the most effective with software for reading instruction. That finding suggests that there may be an interaction between the style and the type of software, the curriculum area of the software, or both. For this study, software for each of three curriculum areas, language arts, science, and social studies was used with each class. Each package was a piece of instructional software: it contained instructional content and design (as opposed to open-ended software such as word-processors, which are used in classrooms but have no inherent instructional content or design). The specific software packages used were selected by this researcher with consideration to published reviews after consultation with the teachers about the upcoming curriculum.

The Puzzler (Gollan, Shillington, Denby, Inkpen, Willer, Burnett, and Miller, 1984) was a set of five stories which provided practice in predicting and confirming while reading.

Those Amazing Reading Machines (1986) provided practice in reading for detail and sequence using animated Rube Goldberg-like machines.

Machines, Work, and Energy (Herzog, 1989) was a tutorial introduction to six simple machines: lever, inclined plane, wedge, screw, wheel-and-axle, and pulley.

Miner's Cave (1988) was a simulation program in which students "lifted" treasure out of caves using one of four simple machines: lever, inclined plane, wheel-and-axle, or pulley.

Women in History (1983) was a game with clues about 34 famous women.

3 Findings: What Could Work Well

3.1 Instructional Software Use

A premise of this research was that some styles would be better for some teachers, for some students, and for some teacher-student combinations. Instead, results indicated that all three styles are valuable, regardless of the primary teaching style of the teacher or the preferred learning style of the student. Each included strategies that seemed to promote the effectiveness of the software. This study suggests that to achieve optimal effectiveness, all three styles should be used to some extent with any piece of instructional software.

The mediating style was defined, in part, as the software being used as a whole-class lesson with the teacher addressing the entire class. Three strategies in that style emerged as important to the effectiveness of the software:

- Demonstrating how to operate the software.

  Students who saw a program demonstrated before individual use had fewer operational questions and more content questions than students who did not have such a demonstration. The operation of some software packages, such as *Machines, Work, and Energy*, is fairly simple. For such packages, the demonstration might involve only a few screens. If the software is more complicated, such as *Those Amazing Reading Machines* or *Miner's Cave*, the demonstration might be a complete example.

- Highlighting the important concepts in the software.

  The teacher can focus the students' attention on the important concepts. The type of guidance and questioning advocated by van Deusen and Donham (1986–87), Bowers (1988), Pogrow (1988, 1990), and Ryba and Anderson (1990) can occur as the class proceeds through the software as a group. Having the important concepts highlighted may also lead to students using software more *mindfully*, which Salomon, Perkins, and Globerson (1991) argued should increase learning. With *The Puzzler*, students needed to be encouraged to think of many different predictions. With *Those Amazing Reading Machines*, students were more focused on the reading when the software had been used with the mediating style than when it had not been. Students in Ms. Reilly's class seemed to use "Master Miner" more thoughtfully after it had been used with the whole class than before.

- Providing benchmarks for definitions of *success*.

  Without being shown what achievement is possible with a software package, students may define success in terms of simplistic operations which do not require understanding the concepts. With *Those Amazing Reading Machines*, after students were told that sound would be added to the machine if they correctly completed the task on the first try, the students tried harder to be successful rather than just guessing. In Ms. Alcott's class, students were given that information as part of using the software as a whole-class lesson. In the other classes, that information was provided on an individual basis. With *Miner's Cave*, students needed to be shown that the goal was not just to lift the treasure but that it was to lift the maximum amount of treasure possible. After they were aware that more treasure could be lifted with appropriate selections, just lifting the treasure was no longer regarded as a success. If students could feel successful without using the concepts, they did not make the additional effort to learn the concepts. However, when they were shown how greater success was obtainable, their old definitions of success were less satisfactory.

With the coordinating style, an important strategy was

- Providing opportunities and time to work with the concepts in a variety of ways.

  For some students in this study, learning took place during use of the coordinated activities and use of the software became practice. These students could not understand the concepts from the software and needed another explanation or medium. Had only the software been available, these students may have required a large portion of the teachers' time for individual explanations or may not have learned the concepts at all.

Two strategies emerged as important aspects of the monitoring style:

- Providing opportunities for students to work with the concepts on their own, at their own pace, when they were solely accountable.

  It seems that if a software package is used only as a whole-class activity student interest is reduced. It was when the students actually used the software themselves that they were engaged with the concepts.

- Providing students (and teachers) a record through which their success and progress can be seen.

  The students in this study seemed very excited when they could measure their success by the scores in *Machines, Work, and Energy*, "Master Miner", and *Women in History*. In many cases, the scoring provided an incentive by establishing a competition between students. Yet, there was also an element of competition with oneself, or of being able to see one's own improvement, which the students found motivating.

The six strategies described above are similar to aspects of the eight principles Brophy and Alleman (1991) asserted for effective implementation of instructional activities: completeness (introduction, initial scaffolding, independent work, and debriefing/reflection/assessment), introduction, initial scaffolding, independent work, feedback, debriefing/reflection/assessment, optimal format, and optimal use of instructional time. While providing an introduction to the purposes of the software was not listed as a specific strategy of any of the styles, one was given for each software package with each style. Initial scaffolding would be provided through the strategies of the mediating style and the monitoring style would provide independent work and feedback. If a software package and its coordinated activities were considered as a set to be an activity, then an optimal format could be selected from that set for learning and practicing the concepts.

These six strategies also incorporate four of the six main aspects of teaching that Ryba and Anderson (1990) argued are necessary for effective use of adventure games as learning tools: facilitating (familiarizing students with the software environment and any prerequisite skills), managing (monitoring student engagement and providing assistance), guiding (asking students about their strategies), modeling (demonstrating how to approach problems), and participating. The aspect that is not explicitly included in these strategies is planning (selecting the appropriate software and the environment for its use).

Just as important strategies included in each style emerged, so did reasons for caution:

- Too much use of the mediating style can cause students to lose interest.

  Even if they liked using the software as a whole class lesson, at some point, students wanted to use the software on their own. They wanted to be able to follow through on their own choices and to proceed at their own pace.

- Demonstration of the software can trivialize the task.

  Miner's Cave could have been, and perhaps was, demonstrated as selecting a machine, getting the maximum mechanical advantage, multiplying the given force by the mechanical advantage, and then selecting the largest load less than that product. Presented in that way, *Miner's Cave* becomes a multiplication drill task. The "why" needs to be included. "If the force is 2 and the mechanical advantage is 3, then what is the largest load that can be lifted? Why? Now select the largest amount of treasure possible." *Those Amazing Reading Machines* could have been presented as, "Study the machine, name and write down each component, then check that list against the description." That methodology, however, could reduce the amount of reading as compared to, "Read the description, take notes of what should happen, then check that list against the machine." In "The Graphics Room", if two of the machines differed from the description in early components, then the descriptions of the later components would not need to be read. The machine that matched the description would be identified by process of elimination.

- Just as instructional software can allow success without learning, so can the coordinated activities.

  One coordinated activity used with *Women in History* was a crossword puzzle with 17 of the 34 women developed by this researcher. The intent was that the students would know a couple of the answers and would be able to determine the rest of the answers from the length of the name and the given letters. However, the crossword puzzle was given before they had studied the women, so it was too difficult. Also, in retrospect, being able to identify a woman by the number of letters in her name, even given a few letters, probably would not encourage learning why that woman was famous. Fortunately, the puzzle could not be totally solved without knowing why at least five of the women were famous. Unfortunately, that was by luck and not by design.

- Rewards, scores, or competition used to monitor student achievement can become more important than the learning.

  Students generally found rewards, scores, and leader boards motivating. Some students liked competing against themselves while others liked competing against other students. Unfortunately, achieving a high score sometimes replaced learning the concepts as the goal. Some students sat literally for minutes trying to decide which woman in *Women in History* was being described by "She is still alive".

  Gourgey (1987) found that students who were rewarded for their progress achieved more in reading than those who were not rewarded. In this study, students in who used *Women in History* with the monitoring style had the lowest average gain score for social studies. However, the type of and basis for reward were very different between Gourgey's study and this one. In Gourgey's study, students were rewarded with praise and stars for good achievement and attendance and with prizes and certificates for exceptional achievement and completion of specific objectives. In this study, students were rewarded with being at the top of a list for getting the best score. But getting the best score did not necessarily depend upon knowing the most women. Students had a list of the women with some information about each one, although one category of information was removed each session. Perhaps those lists provided too much information so the game became an exercise in looking up information on the list rather than learning the women. (The teacher, however, did comment that without those sheets, "I don't think they could have engaged in the first couple of days.") Care is needed to ensure that rewards and competitions foster the learning objectives and not just getting a good score.

This study does not indicate whether the strategies just described can be used effectively apart from the styles with which they were used. It seems reasonable that the most time-effective method of demonstrating the software, highlighting the concepts, and providing benchmarks for success would be to have the software used as a whole-class lesson. However, perhaps students would better learn the concepts if a few students were shown the software by the teacher and they then provided the demonstration to the other students in small groups. The demonstrations would then be more individualized and each student might be more personally involved. There would also, however, be the danger that aspects of the demonstration would change each time it is passed on just as in the children's game of "telephone", where the final message is often unrecognizable as the original message.

The importance of other strategies that were common among these styles is also unknown. Because of the number of computers, students in Mr. Boyd's and Ms. Alcott's classes were forced to work with at least one partner and sometimes with two or three other students. Students in Ms. Reilly's class were able to work alone with *The Puzzler*, *Those Amazing Reading Machines*, and *Women in History*, although they often opted to work in pairs. When students use software other than as a whole class, is it more effective for them to work individually or with some optimal number of others? Does that answer depend upon the software, teacher, students, or some combination of those factors? What is the impact on the effectiveness when students are allowed to select which software they will use as opposed to being told which to use as they were in this study? To echo the earlier calls by Yarger and Harootunian (1978) and Brophy and Alleman (1991), much more research is needed into effective uses of instructional software.

3.2 Instructional Software Development

In subsection 2.1, it was argued that the teaching styles used in this study were styles of use and not styles of the software. However, aspects of a software package can encourage or discourage use of a particular role. For example, the suggestions included in the documentation for *The Puzzler* encourage off-computer related activities and teacher involvement more than does the lack of suggestions in the documentation for *Miner's Cave*. If using the strategies discussed in the previous section (and avoiding the cautions) increases the effectiveness of instructional software, what can software developers include (or exclude) to increase the compatibility of the software with those strategies?

- Software should be designed to complement, not replace, the teacher.

  Software development has not (yet) progressed to the point where programs can do all of the instructional tasks better than teachers. However, there are some tasks that can be more effectively performed by software than by teachers. For example, teachers are overall better at recognizing when a student needs an alternative explanation and providing it than most instructional software, but instructional software can be better at providing unending practice and immediate feedback. Teachers are overall better at providing explanations, but instructional software may be the only practical, if not possible, method of providing a simulation. Software developers need to recognize the limitations of their field and to concentrate on its strengths, rather than trying to accomplish the whole teaching task.

- Instructional software packages should include a demonstration mode that is easy to use.

  Demonstrating the software was effective in this study in allowing students to concentrate on the concepts rather than on the operation of the software. Most of the programs used in this study were easy to demonstrate by using them as a student would with a large screen display. However, demonstrating *Miner's Cave* was more difficult. There was no way to slow down or remove the clock in "Master Miner". The concepts of the program could be introduced through "Miner's Apprentice", which did not have a clock. Yet "Miner's Apprentice" also did not change the cave as "Master Miner" did. When demonstrating "Master Miner", a whole work shift could expire before an initial attempt to lift the load was made. The clock served a purpose when students used the program, but demonstrating the program would have been facilitated if there had been a (documented) way to either slow down or eliminate the clock.

  Another important aspect of a demonstration mode is being able to stop the demonstration at any point. It may not be desirable for students to be able to restart the program at any time, but there should be such a mechanism when the program is used in a demonstration mode.

- Software documentation should include complete information about the program.

  A teacher will be better prepared to demonstrate how to operate the software and to provide benchmarks for definitions of success if complete information is available about the software. While using the software is an excellent, if not preferred, manner to learn about it, a teacher should not, and cannot, be expected to try every possibility in a program before using it with his or her class. Therefore, the documentation is a valuable resource.

  Incomplete documentation can hinder effective demonstration of the software. For example, *Miner's Cave* did not include information about how the scoring was calculated, and there was not time for this researcher or any of the teachers to try to figure it out. Thus, that process was not described to students. All that was said was, "The better the combination, the more points you will receive". It might have been more effective if students could have been told, "For this combination, you will receive 100 points but for this better combination you will receive 200 points". Without having full knowledge of the program, the teacher cannot as effectively demonstrate the use and provide benchmarks for success.

- Software documentation should include suggestions for introducing the software and for relating the software to off-computer activities.

  Off-computer activities provided opportunities and time for students to work with the concepts in a variety of ways. Some software packages, such as *The Puzzler*, include suggestions for introductory, concurrent, and follow-up activities. However, many do not.

  Expecting the teacher to develop all such activities may not appear to be unreasonable. Teachers routinely use texts and games that do not include specific ideas of how to include them in the curriculum. However, such texts and games are not generally promoted as classroom materials whereas most instructional software is so promoted. In addition, publishers have contributed to the belief that instructional software can teach without teacher intervention. They should now share in debunking that myth by suggesting activities to teachers.

- Scores and rewards need to reflect knowledge of the concepts.

  Scores and rewards can motivate student to work with the concepts. However, if students feel they cannot achieve a good score because of the options presented, they can become discouraged. For example, some students complained while using "Master Miner" that they were given a force of one in many caves. They knew that they could not receive a high score because of the low force, which was generated by the program. For that program, a better criterion for being on the "Top Ten" list, rather than raw score, may have been percentage of possible points. The maximum possible score was calculated and displayed to the students, so calculating the percentage of possible points scored would not be very difficult but would give all players equal opportunity regardless of the forces they were given.

Students could also have been penalized by selections made by *Women in History*. Not all the clues uniquely identified a woman. Thus, a student who received a clue such as "She is still alive" or "She was a teacher" would probably achieve a worse score than a student who received the clue, "Her friends and neighbors included Emerson, Hawthorne and Thoreau" even though both students may know the women equally well.

This point is not to argue against random selection by software packages. Rather, it is to emphasize that the score or reward, which students will use to measure their success, needs to be based on knowledge of the concepts. If two students know the material equally, they should have equal opportunities to achieve a good score or reward with the software.

3.3 Teacher Education

The idea of demonstrating the use of an instructional material, providing students time to use it, and providing other activities using the same concepts is not new. Teachers routinely use those three styles with non-computer-based materials. Why do they not use them with instructional software? More importantly, what is needed to enable and encourage teachers to use the strategies previously discussed while using a given piece of instructional software?

- Teachers need to be exposed to ideas.

  Schmidt (1990) told about a visit by Danish teachers to an English school. The teachers were particularly excited about seeing students use a database program. What they found was a program that had been available to them for seven or eight years used in an entirely new manner. "The shocking aspect of it was that no Danish teacher had thought of this possibility so far. ... Of course it is a precondition that [a teacher] actually gets the idea!" (p. 621). In this study, the idea of demonstrating a piece of instructional software using a large monitor was new to the teachers. Perhaps they would have thought of it on their own at some future date, but it cannot be assumed that they would have done so.

- Costs for learning about and trying new methods need to be low. Seeing or participating in a demonstration with classes may lower personal costs for teachers.

Being told about a possibility may not be sufficient for teachers to adopt it. Referring to subsection 1.2, the personal costs may be too high and the perceived benefits too low for them to try to use a new method on their own. Prior to this study, none of the three teachers were aware that the school had the equipment to use a large monitor to demonstrate software. Even if they had been aware of the availability, they did not know how to use the equipment. Asking for help may have had high personal costs for the teachers. They would have had to seek out the appropriate person and arrange a mutually convenient time for a demonstration. Mr. Boyd may have had an additional hindrance. He had previously tried to teach his class how to use a word processor and had been frustrated by that experience. For him, the idea of using an instructional software package in a whole-class lesson may initially have been prejudiced by that negative experience and he might not have have been willing to try it again.

Participation in this study seem to mitigate these problems of not knowing about the equipment, not knowing how to use the equipment, and considering the style to be similar to a previous bad experience. Teachers became aware that the school had the equipment, that all they had to do was request it, and that using the large monitor was no more difficult that using the software itself. Using the mediating style to create a whole-class activity rather than an individual one, as was done with *Women in History*, was also new to the teachers. However, once they were aware of the possibility, they would have had the same technical difficulties as discussed above.

Use of the coordinating style with instructional software was more familiar to Mr. Boyd and Ms. Alcott than was use of the mediating style. They both had used *Voyages of the Mimi* videos and software. However, they had not seriously considered looking for software programs to use as coordinated activities with other curriculum units. Again, seeing the coordinating style demonstrated not only made all the teachers explicitly aware of the possibility, but it also reduced their personal costs in adopting its use. They became aware of specific software packages that were available and appropriate for use with their classes. Mr. Boyd commented that he would like to have many of the programs used in this study. Ms. Reilly felt that her lack of knowledge about available programs hindered her use of computers with her class. Seeing the styles used with classes, especially with their own classes, may reduce the costs to teachers of trying something new.

- Teachers need to be aware of the limitations of instructional software.

  Ms. Alcott "lost a little faith in the role in instruction that computers can play" through participating in this study. She came to believe that computers are better for reinforcing instruction than initiating it. She did not see mastery of the concepts by students, so began to question if the expense was worth the gain.

> I do feel sadder but wiser kind of thing. I still guess a corner of my mind wants to believe there's a way to do this and that computers could actually initiate and reinforce and provide instructional bridges that I can't do myself. But right now I'm feeling in a way it's up to human beings to make sure they know the formulas for different machines or to ensure that they learn about subjects of biographies.

Or, as Ms. Reilly put it:

> The machine hasn't beaten me yet. I'm still better at facilitating knowledge than the computer is. You remember there was some thought five to ten years ago that computers would take over teaching? I don't feel intimidated.

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