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ABSTRACT

This study of "successful" teachers' microcomputer-based mathematics and science instruction had three objectives: (1) to describe how teachers who were nominated by their peers as "successful" microcomputer-using teachers use the technology for instruction; (2) to describe how these uses vary as a function of teacher characteristics and district, school, and classroom contexts; and (3) to make recommendations based on these teachers' suggestions for educating teachers in the instructional uses of microcomputers and for developing courseware that serves teachers' pedagogical aims. Sections in the report after the introduction include: theoretical framework, method, patterns of microcomputer-based instruction, teachers' attitudes and knowledge and teaching contexts, staff development for microcomputer-based instruction, characteristics of teacher-friendly courseware, and conclusions and recommendations. A bibliography is included. (MNS)

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Teaching Mathematics and Science

Patterns of Microcomputer Use

Richard J. Shavelson, John D. Winkler,
Cathleen Stasz, Werner Feibel,
Abby E. Robyn, Steven Shaha

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March 1984

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PREFACE

At a time when American education is perceived to be less than excellent, microcomputers hold great promise for improving classroom instruction by supplementing teaching capability. Several problems impede their widespread implementation, however. These problems derive, in part, from a lack of knowledge of how best to coordinate microcomputer-based instruction with ongoing classroom teaching.

This study of "successful" teachers' microcomputer-based mathematics and science instruction, sponsored by the National Institute of Education (Contract No. 400–82–0006) and The Rand Corporation, had three objectives:

- To describe how teachers who were nominated by their peers as "successful" microcomputer-using teachers use the technology for instruction
- To describe how these uses vary as a function of teacher characteristics (e.g., attitudes, knowledge) and district, school, and classroom contexts
- To make recommendations based on these teachers' suggestions for educating teachers in the instructional uses of microcomputers, and for developing courseware that serves teachers' pedagogical aims

This summary report should be of interest to national, state, and local education policymakers, educators, and courseware developers. It should add to the understanding of how microcomputers may be coordinated with ongoing teaching, how teachers may be educated in their use, and how courseware may be made more "teacher-friendly."

Readers who seek more details regarding the research summarized here should refer to *"Successful" Teachers' Patterns of Microcomputer-Based Mathematics and Science Instruction*, N-2170-NIE/RC (Richard J. Shavelson, John D. Winkler, Cathleen Stasz, Werner Feibel, Abby E. Robyn, and Steven Shaha).

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We are especially grateful to all those teachers, principals, and district staff who gave so generously of their time to share with us their knowledge of and experience with microcomputer-based instruction. While we depended greatly on such diverse and willing assistance, we alone are responsible for any shortcomings from which this report may suffer.

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I. INTRODUCTION

Federal and state policymakers, educators, and the news media all contend that recent technological innovations, most notably the microcomputer, hold promise not only for pulling education out of a "rising tide of mediocrity" (National Commission on Excellence in Education, 1983, p. 5), but also for reshaping education. Not surprisingly, the general public shares this expectation.

When rhetoric meets practice, however, three barriers to the technological promise arise: (1) insufficient numbers of classroom microcomputers to create a significant impact on education; (2) a lack of information on how best to use microcomputers *instructionally* and on how to train teachers to use them; and (3) a shortage of high-quality instructional software (termed *courseware*) to accompany curricula (Office of Technology Assessment, 1982).

Even if microcomputers were widely available in schools, substantial knowledge gaps would still exist that would thwart the potential contribution of technology to improving and perhaps reshaping education. The purpose of this study, in broad terms, was to begin to narrow the knowledge gaps by describing the patterns of microcomputer-based mathematics and science instruction employed by teachers recognized as "unusually successful" in their instructional applications of microcomputers.

More specifically, the study addressed the following questions:

- What patterns of microcomputer-based mathematics and science *instruction* are employed by public school teachers nominated as unusually successful in instructional uses of microcomputers?
- Are these patterns of use related to:
  - District and school policies regarding microcomputers?
  - Organizational and compositional contexts of classrooms?
  - Teachers' attitudes toward computers?
  - Teachers' subject-matter and computer knowledge?
- What do these teachers (and the research literature) recommend about:
  - Educating teachers to incorporate microcomputer-based instruction into their teaching repertoire?
  - Improving the quality of courseware?

In order to address these questions, our strategy was to model the master computer-using teacher and so to provide timely information on exemplary patterns of microcomputer-based instruction. Such patterns might serve as near-term goals for microcomputer-based instruction, for preservice and inservice teacher education, and for the development of courseware. We recognize that today's teaching model may well be tomorrow's anachronism, but we found current knowledge gaps so great that the potential benefits of narrowing them outweighed the potential negative effects of time-bound models.

II. THEORETICAL FRAMEWORK

To characterize instructional microcomputer use, we adapted the theoretical framework referred to as *teacher decisionmaking* (e.g., Shavelson, 1976, 1983; Shavelson and Stern, 1981). This framework describes the process of instruction as it occurs both in the classroom and out (e.g., during instructional planning). The basic premise of the decisionmaking approach is that instruction is an ongoing process, under the active direction of teachers. Instruction is viewed as multifaceted, with goals, content, activities, and teaching methods orchestrated by teachers to provide a flow of activity toward hoped-for outcomes. Teachers' plans are a central focus of this conceptualization. To formulate and evaluate plans, teachers integrate information about students, subject matter, and classroom and school environment. Furthermore, teachers monitor ongoing activities. If activities are proceeding as planned, teachers concentrate on maintaining the flow of activity; otherwise, they activate a routine for handling unplanned events. A final monitoring loop occurs when teachers evaluate the outcomes of instruction in order to improve planning.

This framework helps us recognize patterns of microcomputer use because it suggests specific teaching decisions and tasks in which microcomputers may play a role. We first assume that microcomputer use fits within teachers' ongoing planning and decisionmaking processes. Given this assumption, the decisionmaking framework suggests that classroom microcomputer use should be examined with respect to its *integration* with teachers' ongoing decision processes. Several possible areas for integration can be identified (Winkler and Shavelson, 1982). Microcomputer-based learning activities can be examined with respect to: (a) instructional goals teachers have for students who use them (e.g., achievement, motivation, social skills); (b) features of the curriculum with which they are coordinated (e.g., subject-matter concepts, other course materials and activities); (c) learning activities surrounding their use (e.g., types of courseware assigned, student groupings); (d) pedagogical consequences of their use (e.g., extensiveness of use); and (e) the degree to which they are monitored and may change in response to feedback. These activities, combined in different ways, comprise *patterns* of microcomputer-based instruction. Variations in these patterns were expected to lead to differences in student outcomes (see Fig. 1). Collection of student outcome data, however, was beyond the scope of this study.

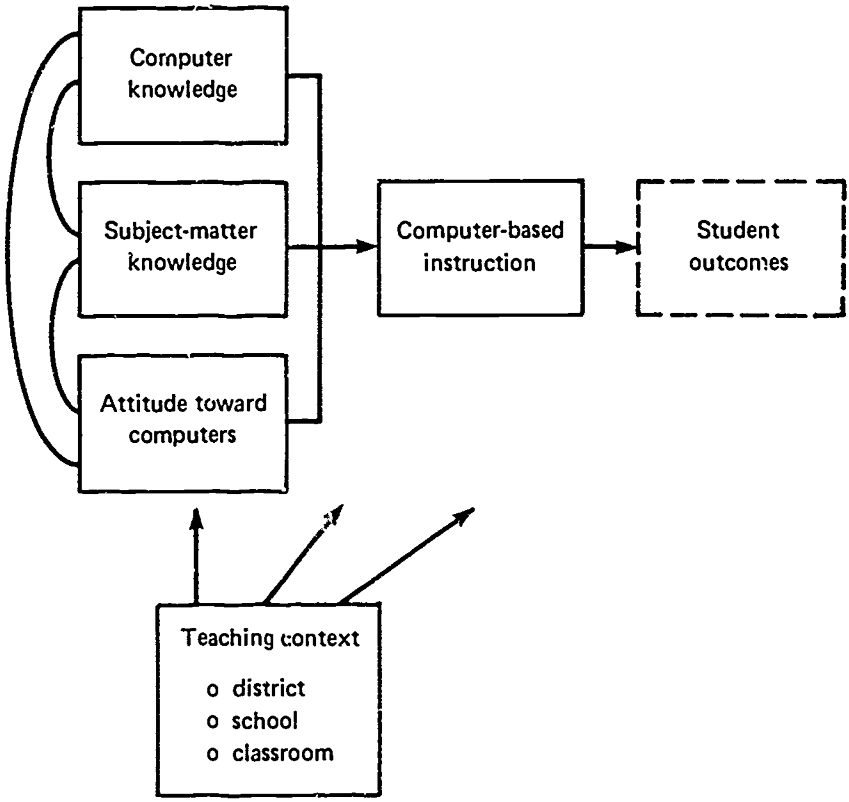

Fig. 1--Conceptual framework

The teachers' decisionmaking perspective also suggests several important inputs to these decisions and activities: the district, school, and classroom context; and teachers' characteristics, including their attitudes and knowledge. Together, the above variables yield a conceptual model, in which various combinations of instructional decisions and tasks using microcomputers are a function of teacher characteristics and contextual variables (see Fig. 1).

III. METHOD

Because this study concerned teaching practices and relationships among instructional variables as they naturally coexist, the research was relational, field-based, and naturalistic, and was carried out in classrooms and schools. We sought to identify patterns of microcomputer use and their concomitants through an intensive study during 1983 of public school teachers who were nominated as "successful" in their microcomputer-based mathematics or science instruction. We also sought these teachers' recommendations for training and courseware, and we determined whether these recommendations reflected variations in their microcomputer-based instruction.

SAMPLE

Teachers in California[1] were the primary sampling unit, and we relied on a "snowball" procedure that solicited nominations of highly regarded teachers from experts in the field—officials in state government and education; administrators of educational computing organizations; district, school, and teacher contacts. Suggestions were followed up through direct telephone contacts and successive screening of candidates, districts, and schools. Teachers nominated as successful were invited to participate if they currently used microcomputers as part of regular classroom instruction in mathematics or science and were responsible for determining the content and form of the microcomputer-based learning activities.

We attempted to achieve an optimal mix among curriculum (mathematics and science), grade level (elementary and secondary), student characteristics (ability and socioeconomic level), and the amount and nature of district and school support for classroom microcomputer use. However, in practice, the selection of teachers, schools, and districts was driven in large part by our ability to locate elementary and secondary teachers of mathematics or science who fulfilled even the minimal selection criteria.

Our original top-down hierarchical sampling plan—to select a few districts whose policies on microcomputers varied maximally, and to

[1]This study was restricted to California for budgetary reasons. Nevertheless, California appears to be representative of microcomputer use in other leading states (Chambers and Bork, 1980), and we sought exemplary uses.

sample schools within these districts, balancing grade level and subject matter of the "successful" teachers—proved unrealistic even in the home state of Silicon Valley. Our initial contacts with districts, schools, and teachers indicated that while microcomputers were used occasionally to teach programming or to foster computer literacy, they were used sparsely and infrequently for mathematics or science *instruction*. Moreover, microcomputer-using teachers described as "successful" seemed to vanish from the classroom to administrative positions, with responsibility for coordinating district computer use, or to positions in private industry. We term this phenomenon the "*vanishing computer-using teacher*."

In the end, 40 elementary and 20 secondary teachers participated in the study. Their teaching experience ranged from 2 to 38 years with an average of 15.8 years. On average, 39 percent of their undergraduate coursework was taken in science and mathematics, 21 percent in the humanities, and 18 percent in the social sciences. All held positive attitudes toward computers.

Overall, teachers indicated that their students were about average in ability (mean = 2.03 on a 3-point scale), but the ability composition of individual classrooms varied from low to high (standard deviation of 0.71). Classrooms were comprised of 38 percent minority on average, but this figure varied greatly from one classroom to another with a standard deviation of 32.31. Indeed, the percent minority ranged from 0 to 98 percent with a mode of 0 and a median of 32.5.

Districts and schools also were diverse in characteristics and policies. Of the 25 districts, 14 were unified school districts, 7 were elementary, and 4 were secondary. Students served in the districts ranged from 5 to roughly 90 percent minority, and their performance on statewide measures of reading and mathematics achievement covered the first to fifth quintiles. The number of microcomputers available for instruction in the districts ranged from 10 to 98, with a mean of 59 and a standard deviation of 38. Districts differed greatly in the manner by which microcomputers had been introduced into instruction; they also provided various degrees of support for their use, ranging from a good deal to none at all. Likewise, schools varied in the number of microcomputers available for instruction (1 to 55 with an average of about 12) and in the resources they provided for microcomputer-based instruction.

PROCEDURES

Once teachers, districts, and schools were selected and scheduled to participate in the study, most of the data were collected on-site, primarily by personal, semi-structured interviews. Each interview was conducted by a single interviewer, who interviewed selected teachers as well as someone knowledgeable about school and district policies on microcomputer use. Teachers were asked about their general instructional decisions and practices, their uses of microcomputers for instruction, and the characteristics of the classroom contexts. The school principal was usually interviewed regarding school policies; district-level respondents included assistant superintendents, curriculum coordinators, and, occasionally, designated computer coordinators. Interviews with respondents lasted approximately one hour. (See Table 1.)

Interviews were augmented with other methods of data collection. We observed how microcomputers were used instructionally in the given learning environment, typically for one class period of about 50 minutes. We also noted the physical context of microcomputer use (i.e., the number, type, and location of available equipment) and examined the courseware used during the observation period. In addition, through a parallel study funded by The Rand Corporation, we obtained biographical data from teachers through a self-administered questionnaire. This provided information on their educational and teaching backgrounds and on their experiences with and attitudes toward computers. Questionnaires were distributed to respondents prior to fieldwork and were returned by mail or retrieved during site visits.

Table 1

SOURCES OF DATA ON MICROCOMPUTER USE

Conceptual Variable	Method	Source of Data
District and School Context	Interview	District and School Administrators
Classroom Context	Interview; Observation	Teachers
Instructional Decisions and Practices	Interview; Observation	Teachers
Microcomputer Use	Interview; Observation	Teachers
Computer Knowledge	Interview; Questionnaire	Teachers
Subject-Matter Knowledge	Interview; Questionnaire	Teachers
Attitudes Toward Computers	Questionnaire	Teachers

At the conclusion of each site visit, interviewers transferred their detailed observational and interview notes onto an extensive questionnaire (rather than writing a formal case study). The questionnaire contained both closed- and open-ended items that elicited data with respect to key variables under study.

All told, data were collected on district and school policies and support for microcomputers; organizational and compositional contexts of the classrooms; teachers' instructional decisions, practices, and microcomputer uses; their subject-matter and computer knowledge; and their attitudes toward computers.

IV. PATTERNS OF MICROCOMPUTER-BASED INSTRUCTION

In order to identify *patterns* of microcomputer-based instruction, we (1) identified instructional characteristics that underlie successful microcomputer-based instruction; (2) created a profile for each teacher according to those characteristics; (3) formed statistically homogeneous *clusters* of teachers on a subset of those characteristics; (4) provided preliminary interpretations of the resulting teacher clusters on the basis of the selected characteristics; (5) examined cluster interpretations using additional characteristics of successful microcomputer use; and (6) described the clusters of teachers, using variables reflecting instructional decisions and practices involving microcomputer use. (For methodological details, see Shavelson et al., 1984.)

TEACHER PROFILE

Based on our theoretical framework, we defined instructional computer use as the *appropriate integration* of *microcomputer-based learning activities* with *teachers' instructional goals* and with the *ongoing curriculum*, which changes and improves on the basis of *feedback*. From this definition, we profiled teachers' microcomputer-based instruction according to 16 variables. The first 5 variables are related to teachers' instructional goals and index the degree to which the teachers stressed microcomputer use for *mastery* of basic skills, *cognitive* understanding, *motivation*, and *management*; the fifth variable indicates whether teachers viewed students' use of microcomputers as a *unique goal*, rather than just as a means of instruction. Another 5 variables are related to features of the curriculum: the degree to which teachers used microcomputers for *instruction, coordinated* microcomputers with other learning activities, and *integrated* microcomputer activities with subject-matter topics; the degree to which teachers *perceived* this *integration*; and whether microcomputers were used by students in the class for activities *other* than mathematics and science instruction. Three variables indexed microcomputer-based instructional activities: the number of different instructional *modes* used (e.g., drill and practice, tutorial, simulation), the number of students typically assigned to the computer (*group size*), and whether students were assigned *equal time* on the computer. The appropriateness of instructional use was judged by the teachers (*perceived success*) and by the field staff (*success*). Finally, we determined whether teachers had modified their instruction based on feedback (*change use*).

PATTERNS OF INSTRUCTIONAL MICROCOMPUTER USE

Recognizing that microcomputers were used instructionally in more than one way, we sought to describe patterns of uses. We used cluster analysis, a statistical procedure, to group together teachers with similar repertoires of use and to distinguish them as clearly as possible from teachers in other groups.

Four clusters emerged from the analysis. Cluster 1 (n = 18), called "orchestration," represented the widest variety of instructional applications closely linked to regular curricular activities. Cluster 2 (n = 23), termed "enrichment," capitalized on available courseware to familiarize students with microcomputers and, as a consequence, integrated computer activities with subject matter and other classroom activities least of any cluster. Cluster 3 (n = 14), dubbed "adjunct instruction," used the computer to augment selected lessons in mathematics and science. Cluster 4 (n = 5), labeled "drill and practice," stressed this instructional mode and basic-skill objectives, and tied computer-based instruction closely to the curriculum and classroom activities. Below, the four clusters are described in detail.

Orchestration Cluster

Cluster 1 was termed "orchestration" because teachers in this cluster stressed both cognitive and basic-skills goals, as well as computer use as a goal in itself; used a variety of instructional modes to meet these goals (e.g., drill and practice, tutorial, simulation, microworld, game); integrated the content of computer-based instruction with the ongoing curriculum, and coordinated computer activities with other instructional activities; changed their uses based on feedback from students; and, not surprisingly, were evaluated as most successful in their use of microcomputer-based instruction during field visits by our staff and by their own judgments (see Fig. 2; for descriptive statistics and statistical tests, see Shavelson et al., 1984). Of the four clusters, the orchestration cluster represented the fullest instructional use of microcomputers by virtue of using microcomputers in ways set forth in our definition above.

Ms. Jones is representative of teachers in the orchestration cluster. She was introduced to microcomputers about seven years ago, when her

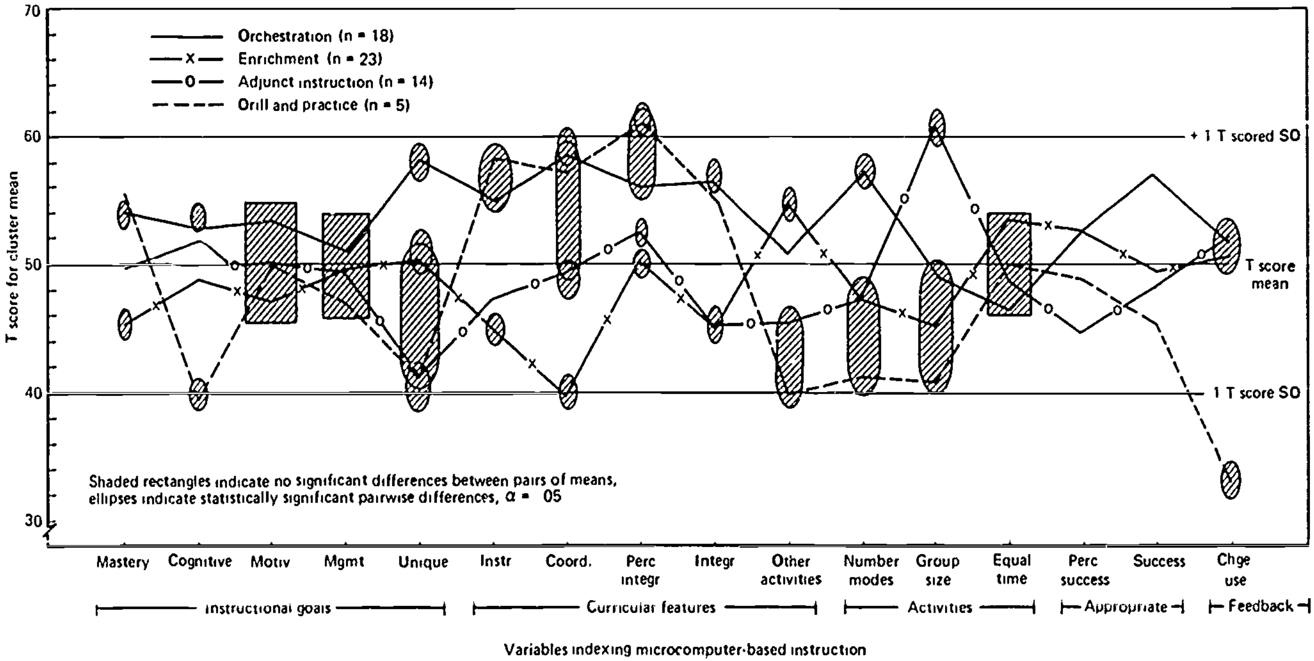

Fig. 2—Profile of similarities and differences among patterns (clusters) of microcomputer-based instruction

husband, a scientist, bought a PET to use at home. Four years ago she began a district pilot project on classroom uses of computers with her own computer. Now she has three PETs in her classroom and more microcomputers in a laboratory.

Ms. Jones teaches 30 mixed-ability third and fourth graders of low to middle socioeconomic background; half are boys and one-quarter are minorities. Microcomputer-based instruction is *integrated* with the major topics covered in mathematics: addition, subtraction, two-place multiplication, division, fractions, and measurement. She *coordinates* computer activities with the textbook, dittoed worksheets, and other instructional aids (e.g., the clock used to teach "time-telling"). She stresses as *instructional goals* for mathematics both mastery of basic skills and acquisition of higher cognitive skills (e.g., analogical relationships and logical thinking); positive attitude toward mathematics is a third, but less-stressed goal. She reports that the computer helps her meet each of the instructional goals; in particular, *drill-and-practice* programs provide immediate feedback in a non-threatening atmosphere. She believes that the microcomputer gives the students a feeling of control, i.e., that the teacher does not control everything. Finally, the computer motivates the students and gives her time to do other things.

Ms. Jones uses the microcomputer as a *teaching aid* for about 20 minutes per week. Her students use the microcomputer *daily*, in the classroom and in the lab, for an average of about 90 minutes of computer-based instruction per week. *Drill and practice, tutorials*, and *simulations* are used most frequently, but *microworlds* (e.g., Kidstuff) and *games* are also used. She also teaches some programming in BASIC. For mathematics instruction, she has three ability *groups*, one assigned to each of the three computers in her classroom. Students usually work *individually* on programs matched to their achievement level, but also work in small groups when courseware requires it.

The computer proved to be more versatile as a teaching aid than she first imagined. As a result, she has *changed* the way she uses her teaching time. For example, she relies on the computer to do remedial *drill and practice* for students who need it, while she uses that time to teach more skills. The microcomputer is also used for student *record-keeping* and *testing*.

In our observation of the classroom, some students worked on the computer with remedial drill-and-practice programs in mathematics while others used the word processor to write stories. (Ms. Jones uses the computer for *other subjects* besides mathematics; the "storywriters" were working on an English assignment.) The atmosphere was chaotic—to be expected when 30 eight- and nine-year-olds occupy one-third of a "pod" in an open-plan school. In spite of the chaos, there was a feeling of order in the activity, and students were thoroughly engaged in either their seatwork or computer activities.

In addition to teaching, Ms. Jones serves as the computer resource person at her school and district, and she teaches many of the staff development courses. In her "spare" time she reviews courseware, writes or modifies courseware, and writes articles about computers. In the summer, she turns her kitchen into a computer learning laboratory for children six to thirteen years of age and their teachers.

Enrichment Cluster

Teachers in the enrichment cluster were least inclined to integrate computer-based instruction with the ongoing curriculum, to coordinate this activity with other classroom activities, or to use the microcomputer to help students master basic skills. Thus, they tended to use microcomputers less for instruction than did teachers in clusters 1 and 4. However, teachers in this cluster were most likely to use the microcomputer in instruction in subjects other than mathematics or science, or for word-processing. And more teachers in this cluster than in clusters 3 and 4 encouraged microcomputer use for its own right. This suggests that their computer use was somewhat ad hoc and served as an end more than as an instructional means. Although these teachers, on average, considered themselves as successful in microcomputer-based instruction as teachers in the orchestration cluster, staff field evaluations were less positive (Fig. 2).

Mr. Higgins is representative of the teachers in this cluster. He became involved with microcomputers through a combination of initiative and strong support from his principal, Mrs. Castillo. He took his district's elective staff development workshops, and attended some classes at Radio Shack on his own. He requested a microcomputer for his class, and Mrs. Castillo acquired a TRS-80 with the help of the district math curriculum coordinator, Mr. Blum. Mr. Blum is also strongly supportive of microcomputer use in the district schools, but has few resources to provide. He purchased a handful of TRS-80s for the district with Chapter 1 funds, and uses a limited amount of administrative funds for occasional purchases of courseware. These are in turn passed along to teachers such as Mr. Higgins.

Consequently, Mr. Higgins currently has a limited amount of courseware available for his class of fifth and six graders that he describes as low in ability and in socioeconomic background and which we observed was composed of nearly 90 percent minority students. His philosophy of microcomputer instruction is to use the courseware to give each student the *opportunity* to spend some time with the microcomputer. He has established a sequence in which students progress from *basic-skills* programs in math and spelling, with drill and practice, into programs that exercise dictionary and logic skills, and thus enhance *reasoning ability*. Once students demonstrate proficiency in these lessons, they have a "free choice" period; games are among the options available.

Mr. Higgins posts a daily schedule for students' computer use on the blackboard. Each student spends ten minutes a day on the microcomputer—50 minutes a week. Luis, a student aide, keeps track of the schedule, supervises the operation of the machine, and makes sure that each student has the appropriate courseware. This involves updating the spelling program with the students' words for the week and placing the students at the correct level of the math sequence. Thus, although all students use the same courseware, the lesson content is individualized according to the student's ability. Nevertheless, the vast majority of programs are drill and practice.

These computer activities occur independent of concurrent classroom activities, as is characteristic of elementary classrooms. During the period in which we observed the class, some students read a history lesson and engaged in seatwork; others participated in a reading circle with the teacher. Mr. Higgins admits that the degree of *coordination* between microcomputer activities and other class activities is minimal, and that high-quality courseware coverage of topics in mathematics and language arts is limited. He is satisfied, however, to note that the microcomputer is occupied by a student nearly all day and that the students enjoy the activity. He feels that as he gains more experience, he might be able to find some additional courseware to round out his instructional program.

Adjunct-Instruction Cluster

Teachers in cluster 3 were distinguished by their grouping decisions—they provided computer-based instruction to students in groups of two or more. Moreover, they confined microcomputer use to mathematics or science subjects, emphasizing cognitive goals, in a catch-as-catch-can manner that was not as closely integrated with the ongoing curriculum as was common among teachers in other clusters. Unlike teachers in cluster 2 who try to use the microcomputer to provide a wide range, even if a somewhat limited amount, of instruction, the approach of the cluster 3 teachers appears to be to selectively augment certain lessons, and not to view microcomputer use as a goal in itself (Fig. 2).

Ms. Fast is representative of the teachers in the adjunct-instruction cluster. She has taught with computers in her classes for almost four years, after being introduced to them by another teacher who had two terminals connected to a mainframe computer. She has taken training courses in educational technology offered through the district, as well as courses on her own, at a local state university. Regarded now as one of the two computer experts at the school, she actively promotes the use of computers in instruction. She feels that the pace of microcomputer implementation and training is much too slow, that more extensive training programs for teachers are needed, and that the training should place less stress on programming.

We observed Ms. Fast's tenth grade biology class of 30 students, about half of whom were female and about 55 percent of whom were minorities, comparable to the school's ratio according to her. The students came from low to upper-middle income families, and most were of average to high ability.

Ms. Fast uses microcomputers to help attain the *goal* of higher-level cognitive skills, such as problem solving and reasoning. She also considers it important to use microcomputers to help give her students a feel for science as a process applicable to real-world situations, and to motivate scientific thinking skills in the students. She does not emphasize basic skills (possibly because her class does not require it) and does not include class management as one of her major goals for the class. Finally, she uses the computer to reinforce vocabulary and concepts for weaker students.

To help achieve her goals, she uses computer *simulations* in her classes. Students read and discuss a topic (e.g., laws of population genetics) in class. Then they explore the variables and relationships by using a simulation program. These simulations thus reinforce the understanding from the reading and discussion. Her students work at the computer in pairs, with a lab partner they select at the start of the year. Having *students work together* allows them to interact with each other as well as with the program, thereby helping reinforce the view of science as process. The strategy also helps alleviate the problem of access to the computer; each student uses the computer only about three times in the semester, for about 10 minutes each time.

When possible, students work on the *same content* at the computer and in class; however, this is not always possible for reasons of both hardware and software availability. Ms. Fast did *not emphasize* the *integration* of computer materials with other aspects of the course because she felt that too little courseware of sufficient quality was available.

Drill-and-Practice Cluster

The number of teachers in cluster 4 was small (roughly 8 percent of the sample), but the teachers were homogeneous in their use of microcomputer-based instruction. Each used drill and practice extensively and almost exclusively to achieve mastery of basic skills in mathematics or science (Fig. 2). Microcomputer-based instruction was not used for the acquisition of higher-order conceptual skills, nor were microcomputers used to develop skills in using information technology. Computer-based instruction was delivered to students individually, was closely integrated with the ongoing curriculum, and was closely coordinated with other classroom activities. These teachers had not changed their computer use since implementing it.

Mr. Greg is representative of the five teachers in this cluster. About five years ago he was hired by his district as a mathematics-resource teacher and charged with raising the test scores of seventh and eighth graders, half males and three-fifths minorities, all of whom are low in ability and SES. He responded by developing an entire mathematics curriculum from whole numbers to geometry with the help of volunteers, acquiring a laboratory full of microcomputers with Title I funds, and *linking drill-and-practice* courseware written by an unemployed programmer *to the new curriculum.* Moreover, he accomplished all this without formal training in instructional microcomputer use; indeed, he has since pioneered such use in other districts.

His classes, averaging about 32 students each, are divided into four groups. He tutors students in one of these groups while students in the other groups are tutored by the three aides supported by Chapter 1 funds. Every fourth day, students are sent across the hall to a laboratory where a lab coordinator oversees their 50 minutes of drill and practice on mathematics problems *linked directly* to the *curricular strand* they are studying in class.

Mr. Greg's major instructional *goal,* in broad terms, is student *mastery* of *basic skills.* More specifically, he found that his students needed a great deal of practice in mathematics computation if they were to raise their test scores. Given the importance of practice in computation, he *uses only drill-and-practice* courseware in the microcomputer-based instruction. Hence, the microcomputer is a major partner in helping Mr. Greg substantially improve his students' mathematical skills.

Observations of students in the laboratory confirmed what Mr. Greg had told us about his instructional goals and plans. Students *worked individually* on a network of microcomputers, receiving drill and practice on topics ranging from addition to algebra, depending on the student's curricular strand. The *courseware tracked* each student's *performance* and required the student to satisfactorily complete one strand before moving to the next. The lab coordinator moved from one student to the next, providing instructional help when asked. Without exception, the students were "glued" to the computers by interest; our presence went unnoticed after the first minute or so.

V. TEACHERS' ATTITUDES AND KNOWLEDGE AND TEACHING CONTEXTS

Variations in the patterns of microcomputer-based instruction might be associated with teacher characteristics such as their attitudes toward computers, their knowledge of the subject matter taught, or their knowledge of microcomputers themselves. Or variations might be associated with district implementation and support policies, or school building resources and incentives. Or perhaps microcomputer use reflects such classroom conditions as the nature of the students or the proximity of microcomputers to the classroom.

A resolution of the sources of variation in microcomputer-based instruction may bear on policies for teacher selection and training. If relationships are found, information on teachers' attitudes and subject-matter background, for example, might, along with other kinds of information, enter into a district's decision about the types of teachers to hire or train. Moreover, information on teachers' computer knowledge might be used, along with other information, to establish a curriculum for preservice or inservice education.

Individual differences among teachers in their attitudes and knowledge cannot and do not account for all the variability in microcomputer-based instruction. There are contextual factors that encourage, discourage, or set limits on the kinds and range of instructional uses teachers may employ. School district policies regarding amounts and kinds of hardware and courseware might influence computer use. School-building policies that support and encourage computer use might affect the prevalence and kinds of use. The nature of the students served in the classroom might affect the modes of instruction employed. Selection and training decisions, then, might depend on the particular context in which instruction is delivered.

Information about teacher characteristics, and the classroom contexts in which they teach, may have social-policy implications as well. There is growing concern over "computer equity," equity of access to the new technology, the knowledge and skills needed to use it, and the roles this technology can play in society (e.g., *The Computing Teacher*, 1984; Becker, 1983; Lipkin, 1982; Reisner, 1983; Walker, 1983). Our data, for example, can be brought to bear on claims that low-income minority students receive systematically different kinds of microcomputer-based instruction than do other students.

TEACHERS' ATTITUDES AND KNOWLEDGE

Teachers' Attitudes

Teachers' attitudes toward microcomputers were unrelated to the patterns of microcomputer-based instruction; all teachers held uniformly positive attitudes. In a group of teachers nominated as unusually successful in their microcomputer use, this finding was not unexpected.

Teachers' Subject-Matter Knowledge

A teacher's subject-matter knowledge, especially in mathematics and science, might reasonably be expected to influence patterns of microcomputer-based instruction, especially in those subject matters. This seems to be what some politicians and policymakers had in mind when mathematics and science teachers were suggested as the potential leaders of the microcomputer movement in education (e.g., National Science Board Commission, 1983).

In lieu of direct and extensive testing of teachers' subject-matter knowledge, something not feasible in this study, we settled for a proxy measure of knowledge. Teachers were asked to indicate the percent of their undergraduate coursework spent in science, mathematics, computer science, social science, humanities, and education. We then examined the relations between these indicators of knowledge and patterns of microcomputer-based instruction.

By and large, our findings corroborated those of research on the relation between teacher knowledge and student outcomes: There were not systematic (statistically significant) differences among patterns in average percentages of coursework taken in mathematics, computer science, social science, humanities, and education.

Microcomputer-based instruction did vary systematically, however, as a function of the amount of science taken in undergraduate coursework. Teachers in the drill-and-practice and adjunct-instruction clusters took, on average, considerably more coursework in science (39 percent) than did teachers in the orchestration and enrichment clusters (16 percent). In general, teachers in the drill-and-practice cluster took less coursework in mathematics (13 percent) and even less in social science (7 percent) than did teachers in the other three clusters (16 and 19 percent in mathematics and social science, respectively). In contrast, the orchestrators tended to take, on average, the least coursework in science (14 percent) and the most in mathematics and social science (17 and 26 percent, respectively).

Teachers' Computer Knowledge

One might expect that variations in knowledge of computer hardware and software would be related to different patterns of microcomputer-based instruction. More knowledgeable teachers might use a wider range of instructional modes, or might select courseware that makes fuller use of the hardware's capabilities.

As with subject-matter knowledge, we sought a measure of teachers' knowledge that could be obtained easily and unobtrusively with their cooperation. This ruled out testing. Instead, we asked teachers questions related to how extensively they had used computer hardware and courseware. We also asked whether they had served as computer resource person for their schools or as instructor for staff development. Finally, we asked how many programming languages they had used. Our rationale was that self-reports of behavior regarding microcomputer use provided experiential indicators of computer knowledge. In addition, however, interviewers rated each teacher's courseware and hardware knowledge.

Patterns of microcomputer-based instruction were unrelated to teachers' experiences in using microcomputers or in teaching other teachers about them, and unrelated to programming ability. Teachers had used, on average, about 25 different educational programs during the school year, applied computers outside their work in a number of different ways (e.g., word processing, data analysis), used several different types of hardware, and wrote in at least one computer language, primarily BASIC. Approximately 70 percent of the teachers had taught other teachers or district staff and 85 percent had served as school resource person.

Interviewers' ratings of teachers' *courseware* knowledge, however, did vary systematically with instructional use. Teachers in the orchestration cluster were rated as significantly more knowledgeable about courseware than teachers in the drill-and-practice cluster. This finding is, perhaps, not unexpected since the latter teachers primarily used one type of courseware whereas the orchestrators were distinguished by their use of multiple modes of microcomputer-based instruction.

TEACHING CONTEXTS

District and School Context

Recognizing the potential importance of the district and school context, we collected data on the extent to which the 25 districts supported the implementation and the instructional use of microcomputers, and on the extent to which the 49 schools (principals) supported and provided incentives for microcomputer use. The central question behind our analyses of these data was: "To what extent, if any, were district and school context factors related to the different patterns of instructional use we observed?"

Without exception, the answer to this question was *none*. Across clusters, most teachers were found, not surprisingly, in districts where (a) the impetus for microcomputers came from teachers, (b) microcomputers were supported, at least to some extent, but (c) microcomputers were not included in the district budget as a line item. About half the teachers were drawn from schools that provided personnel support for computer use, and roughly two-thirds were offered some kind of incentive for using computers—primarily release time to attend computer workshops. By and large, the responsibility for implementing microcomputer-based instruction fell squarely on the shoulders of the teachers.

Classroom Context

The organization and composition of students in classrooms profoundly affects instructional processes and outcomes and thus might be expected to affect microcomputer-based instruction. For example, warnings and recent findings have suggested that low-achieving, minority students may be more likely to receive drill and practice while high-ability, majority students may be more likely to receive creative problem-solving instruction on the computer.

Through interviews and observations, we collected data that bear, in a limited way, on the relation between classroom context and microcomputer-based instruction. With respect to organization, we collected data on the number of microcomputers available for instruction and their proximity to the teachers' classrooms. Since elementary schools are organized around self-contained classrooms while secondary-school classrooms are organized by subject matter, we included this grade-level distinction. As for classroom composition, teachers estimated the percentage of minority students in their classes and the ability levels of their students.

Patterns of microcomputer-based instruction proved to be unrelated to organizational variables. On average, about five microcomputers were available to teachers in the schools studied, but this number varied greatly within a cluster. Slightly more than half the teachers took their students to laboratories, and variations in instructional pattern were not related to grade level.

In striking contrast was the finding that patterns of microcomputer-based instruction were related to classroom composition. Minority percentage and ability level were both associated with instructional pattern (see Fig. 3). Classrooms above average in ability and low in minorities tended to be those of teachers who "orchestrate" the ongoing curriculum with a wide variety of microcomputer-based instructional modes stressing both skill acquisition and conceptual knowledge. As ability level decreased and minority percentage increased, microcomputer-based instruction tended toward enrichment and adjunct instruction. The five classrooms with a high percentage of minority students (mean = 64.40) who were low in ability (mean = 1.20 on a scale from 1 to 3) employed microcomputers to deliver drill and practice on the basic skills taught in class.

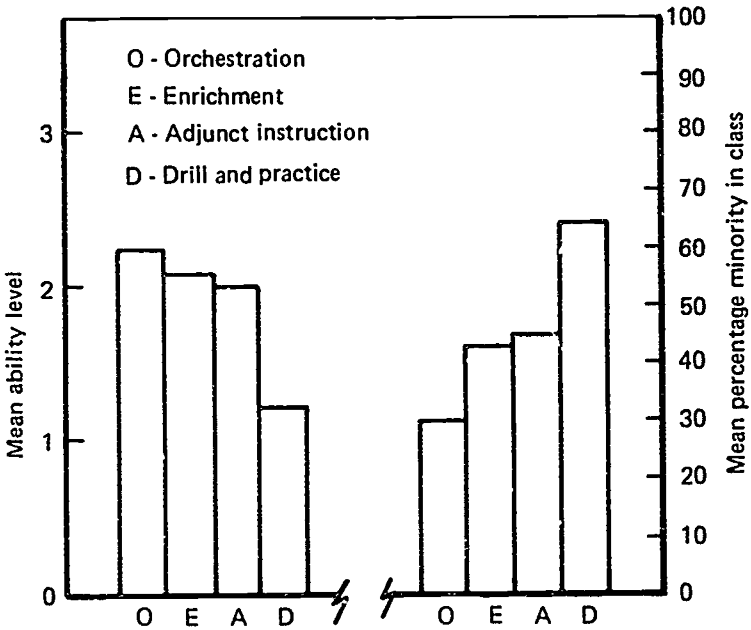

Fig. 3—Relationship between pattern of microcomputer-based instruction and classroom composition

VI. STAFF DEVELOPMENT FOR MICROCOMPUTER-BASED INSTRUCTION

The lack of adequately trained teachers is a major obstacle to effective microcomputer-based instruction in schools. The obvious solution is to train preservice and inservice teachers to use microcomputers instructionally (see, e.g., Office of Technology Assessment, 1982; Poirot, 1980; Taylor, Poirot, and Powell, 1980). But educators lack the experience and knowledge base to select topics for training or to organize this training.

To begin compiling a research base for these decisions, we asked "successful" teachers for their recommendations for the content and organization of training, and then ascertained whether their recommendations varied according to their patterns of microcomputer-based instruction. More specifically, we asked teachers to describe the *topics* or content that should or should not be included in staff development for instructional microcomputer use, and to describe the *organizational features* of such staff development, especially location, duration, and incentives. We also asked whether the content of preservice education should differ from that of inservice education and, if so, in what ways.

TEACHERS' RECOMMENDATIONS FOR STAFF DEVELOPMENT

We found that teachers' recommendations did not systematically vary according to the patterns of their microcomputer-based instruction or according to the grade level they taught. This was true of their recommendations for content and organization.

Content Recommendations

A consensus emerged among teachers on which topics are important; their recommendations are consistent with those found in the literature (e.g., ACM, 1980; NEA, 1983; Office of Technology Assessment, 1982; Page and Wallig, 1983; Sheingold, Kane, and Endreweit, 1983; Sobol and Taylor, 1980). In order by number of teachers recommending them, the topics were: operation of the microcomputer (n = 47), selection/evaluation of courseware (n = 30), programming (n = 30), instructional uses (n = 29), computer literacy (n = 28), integration with instruction (n = 22), no programming (n = 12), and administrative uses (n = 10).

The conflict in the teachers' recommendations regarding programming reflects the current debate in the literature. While some advise that instruction in programming should be avoided at the introductory stages (e.g., Hamolsky, 1983; Nanson, 1982), others assert that programming is essential for teachers (or anyone) to become computer-literate (e.g., Luehrmann, 1981). Between these extremes are those who advocate some introduction to a programming language (usually BASIC) as a way to understand the nature of computers and programming (e.g., Page and Wallig, 1983; Widmer and Parker, 1983).

The fact that some teachers did not want programming included in staff development is noteworthy, both because of the controversy and because it was the only topic to receive any definite "no" votes from the teachers. Moreover, 18 teachers, mostly elementary teachers, did not mention programming at all. This suggests that elementary teachers did not consider programming important enough to include it as a topic for staff development.

Organizational Recommendations

Teachers' recommendations regarding the organizational features of staff development can be summarized succinctly as a series of meetings (n = 23), held during school hours (n = 4) or after school (n = 6), located on-site (n = 23), averaging about 13 hours in duration with as much hands-on practice as possible (n = 12). One additional recommendation was to involve students in the staff development activity as a way to see how the courseware works with its intended audience.

Some teachers also recommended varying staff development activities in level of sophistication (n = 7) and topic (n = 4), in order to meet the needs of teachers at different stages of microcomputer use. For example, they suggested offering programming as more advanced instruction for those who wanted to learn that skill. And they recommended organizing workshops around specific topics so that sessions could be attended selectively, based on need.

The teachers also mentioned staff development incentives including salary (n = 27) and release time (n = 18). However, one-third said that incentives were not necessary. Teachers who opposed incentives felt that they would encourage some teachers to become involved for the wrong reasons; those in support argued salary credits or release time were effective. One unique suggestion was to give credits to purchase computers or courseware.

Teacher incentives are the most pressing organizational issue in the research literature. Currently, some school districts use a variety of incentives to maximize teacher participation in staff development programs, outside computer courses, conferences, and other activities to broaden computer experience and expertise. These incentives include incremental salary credit (Sheingold et al., 1981; Page and Wallig, 1983), reimbursement for outside courses (Coburn et al., 1982), release time (NEA, 1983; Office of Technology Assessment, 1982), and new job titles with higher salaries for technically experienced teachers (Office of Technology Assessment, 1982). After initial training, other organizational incentives—such as providing computer-resource personnel (Sheingold et al., 1981), loaning computers to teachers over weekends, vacations, and summers (Sherman, 1983), and subsidizing teachers to author courseware (Office of Technology Assessment, 1982)—encourage teachers to increase their computer knowledge.

Preservice Education Recommendations

Almost all teachers recommended incorporation of microcomputer-based instruction in preservice education programs. Some said that computers should be included as part of the audio-visual block, while others felt that a semester-long course on computers should be offered.

About half felt that preservice training programs should differ from inservice staff development. Some recommended additional breadth in the preservice course, perhaps to compare different types of computers or explore various ways that computers can be used as teaching tools.

VII. CHARACTERISTICS OF TEACHER-FRIENDLY COURSEWARE

There is almost universal agreement that the quality of currently available courseware is in general poor, and the extent of curricular coverage highly restricted (Becker, 1982; Chambers and Sprecher, 1983; Office of Technology Assessment, 1982). Yet most educators and policy analysts agree that high-quality courseware is essential for computers to make a significant contribution to education (Braun, 1977; Chambers and Bork, 1980; *Electronics*, 1983; Molnar, 1977a,b; Office of Technology Assessment, 1982).

One impediment to the realization of teacher-friendly courseware is the current lack of communication between educators and courseware developers, as evidenced at an NIE conference in Fall, 1983. Both parties talked past one another on key issues (*Education Daily*, September 15, 1983, pp. 3–4):

Educators	*Courseware Providers*
"Too many trivial drill-and-practice programs"	"Nobody knows what teachers want"
"Too many high-cost programs"	"Schools pinch pennies in purchasing courseware"
"Too little opportunity to review programs"	"Schools illegally copy programs"

TEACHERS' RECOMMENDATIONS FOR COURSEWARE IMPROVEMENT

To begin to bridge the communication and knowledge gap, we solicited "successful" teachers' recommendations for quality courseware, examined whether these recommendations varied according to differences in the patterns of their microcomputer-based instruction, and integrated these findings with the literature on courseware development to reach recommendations for improving it. More specifically, we asked teachers four questions: (1) Do you, your school, or district have standard criteria for evaluating courseware, and if so, what are they? (2) What features do you look for in selecting courseware? (3) What features do you try to avoid? and (4) How could courseware be improved, based on your experience? As expected from an open-ended interview, some teachers had much to say; others did not. Forty percent of the recommendations came from 25 percent of the respondents. Patterns of microcomputer-based instruction were, with few exceptions, unrelated to the nature of the courseware recommendation. Very broadly, teachers' responses concerned the following courseware attributes: the general *friendliness* of a program, such as the clarity of its instructions or the ease of its operation, and friendliness to the teacher, such as its modifiability; courseware *content*, such as the coordination of its topics with a particular curriculum; *pedagogy*, such as requiring the student to think critically; *computer use*, such as the extent to which the courseware fully uses hardware capabilities (e.g., graphics); and issues related to the *selection* and *acquisition* of courseware.

Friendliness

Teachers in all four clusters (n = 10 teachers) stated that friendly courseware is "crashproof"—does not stop running for reasons unknown to the user. Although this would seem to go without saying, our classroom observations revealed that a great deal of time—on the part of teachers and their student aides—was spent troubleshooting programs that had crashed. Moreover, in some cases, students sat idle for almost an entire period, waiting to have the program fixed. Another attribute of friendly courseware (n = 25) is ease of use, including clarity and simplicity of instructions for using courseware, on-line instructions, and good documentation.

Teachers also recommended that courseware should be modifiable to fit their curriculum and their students' needs (n = 8). For example, teachers might modify the number or type of problems presented, the specific information communicated, or the length of a session. Or they might modify the program to skip certain instructions, personalize an interaction with a student, or network a set of microcomputers. Finally, the teachers wanted recordkeeping (management facilities) incorporated into the courseware.

Content

Teachers sought courseware that was closely coordinated with textbooks and other instructional materials (n = 12). Moreover they said that courseware should be firmly grounded in and mindful of important concepts in the subject matter, in addition to facts (n = 8). That is, they looked for programs that enhance conceptual understanding well as procedural mastery. Finally, they recommended that courseware should be free of errors of content, grammar, and spelling, which occur in current courseware to a surprising degree (n = 4).

Pedagogy

To enhance students' learning experiences with courseware, the sample of "successful" teachers recommended that courseware require the learner's *active* participation (n = 5), that levels of difficulty be appropriate for the students (n = 9), and that courseware teach "thinking and problem-solving skills" (e.g., to formulate hypotheses, apply knowledge to novel problems) as opposed to memorization of facts (n = 7). They further recommended that the courseware contain material on a topic at more than one level of difficulty (n = 4), that the program be capable of branching based on student performance (n = 4), and that the courseware provide sophisticated diagnostics to students on their conceptual difficulties with the material (n = 6). Finally, they recommended including teachers in courseware design (n = 11) because teachers are likely to be knowledgeable about most of the pedagogical characteristics of courseware (e.g., difficulty level, areas of conceptual confusion, alternative ways of teaching a topic).

Uses of the Computer

Teachers wanted courseware to fully and effectively use the computer's capabilities, going beyond the "electronic workbook." They expected courseware to use graphics (n = 12); some also mentioned other modalities, such as the use of sound and color (n = 5). Nevertheless, the teachers did not support the uncritical use of these facilities; rather, they called for moderation where appropriate. Finally, some considered an arcade or game format desirable for courseware (n = 9).

Selecting and Acquiring Courseware

With respect to courseware selection and acquisition, teachers, especially those in the enrichment cluster, mentioned the high cost of courseware, expressed a desire to evaluate it extensively before purchasing, and wanted more liberal arrangements for making backup copies of the courseware (e.g., for networked configurations).

VIII. CONCLUSIONS AND RECOMMENDATIONS

This study sought to: (a) describe how teachers, nominated by their peers and other educators as "successful," use microcomputer-based mathematics and science instruction in their classrooms; (b) account for variations in these teachers' patterns of microcomputer use according to their attitudes and knowledge, and district, school, and classroom contexts; and (c) recommend policies, based on these teachers' suggestions and the research literature, for staff development and courseware improvement. This section presents our conclusions and recommendations.

PATTERNS OF MICROCOMPUTER-BASED INSTRUCTION

Three conclusions emerge from this search for and description of teachers characterized as "successful" in their use of microcomputer-based mathematics and science instruction. The first conclusion is that even in California, a state touted for high technology and enlightened policies regarding microcomputer-based instruction, "successful" teachers were extremely hard to find in the fall of 1982 and winter of 1983. The search was complicated further by the phenomenon of the "vanishing computer-using teacher": Teachers nominated as successful in educational applications of microcomputers disappeared from their classes to become "computer coordinators" in their districts or software developers in the burgeoning information technology industry.

Policies for retaining these talented teachers in the classroom need to be explored. For example, current teacher salaries cannot compete with administrative and private sector salaries. Merit pay schemes for increasing salaries might improve salary leverage, although they may not if the increases are small or unpredictable from year to year. Equally, if not more important, is the improvement of working conditions. One way of improving working conditions and, perhaps, of avoiding the vanishing-computer-using-teacher phenomenon is to provide these talented teachers with increased responsibility for hardware and courseware acquisition and for training their peers. This increased responsibility would, of course, have to be accompanied by adequate budgets and budgetary control, by release time to perform these added functions, and by a considerable incentive for this special expertise. For example, positions for "computer buffs" might well be built into a career ladder or pay scale. If teaching conditions are not improved for these successful computer-using teachers, microcomputer-based instruction may not achieve its potential, and children will not benefit fully from the technology.

The second conclusion is that microcomputer-based instruction by teachers dubbed "successful" by their peers, other educators, and administrators is not monolithic. These teachers vary greatly in: (a) their goals for microcomputer-based instruction (e.g., mastery of basic skills, acquisition of conceptual reasoning, or both); (b) the degree to which they used microcomputers instructionally, integrated computer-based instruction with the ongoing classroom curriculum, and coordinated computer activities with other instructional activities; and (c) the extent to which they varied the modes of microcomputer-based instruction, ranging from almost exclusive drill and practice to the orchestration of multiple modes, including drill and practice, tutorials, simulations, microworlds, and games.

These differences in the microcomputer-based instruction of "successful" teachers were systematic and were captured by a statistical grouping of teachers into four homogeneous clusters: orchestration (n = 18), enrichment (n = 23), adjunct instruction (n = 14), and drill and practice (n = 5). Teachers in the orchestration cluster emphasized both basic skills and conceptual goals; integrated microcomputer-based instruction with the current subject matter, and coordinated class and computer activities closely; and employed multiple modes of instruction on the computers. Teachers in the enrichment cluster were least inclined to integrate computer-based instruction into the curriculum. They emphasized something akin to computer literacy within a limited instructional program. Teachers in the adjunct-instruction cluster were distinguished by their grouping of students for microcomputer-based instruction to selectively augment certain lessons. Finally, the five teachers in the drill-and-practice cluster were homogeneous in their extensive and almost exclusive use of drill-and-practice programs that were integrated with the ongoing curriculum and closely coordinated with classroom instructional activities, and in their not having changed computer use since implementing microcomputers.

The similarities among these teachers, regardless of cluster, are equally informative. In general, the teachers did not stress the use of microcomputers for motivating students or for keeping students' records or testing them. They typically assigned equal amounts of time at the microcomputer to all students—about an hour per week. Most had established rules for the operation of the computer and for governing talking while working with the computer. Most teachers assigned material to students on the microcomputer by matching content with difficulty and (less typically) by matching instructional mode to student need; they were also opportunistic, assigning students to special software when it became available. Finally, over two-thirds of the teachers reported that their schools and districts provided courseware and that they participated in courseware selection decisions.

The third conclusion is that this diversity in the patterns of microcomputer-based instruction is probably due to a number of factors, such as teachers' attitudes toward computer-based instruction, their knowledge of subject matter and of computers, and the context in which they teach. By context we include the nature and needs of their students and the policies and support of district and school administrators. Until such factors are considered, an overall evaluation of the different patterns of microcomputer-based instruction is premature.

FACTORS RELATED TO PATTERNS OF MICROCOMPUTER-BASED INSTRUCTION

The findings on the relationships among patterns of microcomputer-based instruction and teacher characteristics and district, school, and classroom context are potentially startling. Paramount is the finding that students in classrooms characterized as low in ability and high in percentage minority received computer-based instruction primarily from drill-and-practice programs, while students in classrooms characterized as high in ability and low in percentage minority received instruction from a myriad of computer programs, including drill and practice, tutorials, simulations, microworlds, and games. If the medium is the message, the message delivered to students in the former classrooms is substantially different from the message received by students in the latter.

Moreover, contrary to the advice of the National Science Board's Commission on Precollege Mathematics, Science and Technology Education, science teachers may not be the primary ones to lead the technology revolution in education. Teachers with extensive undergraduate coursework in science tended to fall into either the adjunct-instruction or the drill-and-practice cluster. Teachers in the former cluster tended to limit computer-based instruction to drill and practice or simulations in the subject matter, while teachers in the latter cluster tended to use only drill-and-practice programs, for basic-skills instruction.

Equally surprising is the finding that, implementation research notwithstanding, district and school policies on support for microcomputer-based instruction were unrelated to the patterns of instructional use. Rather, patterns of use were systematically related to differences in subject-matter backgrounds of teachers, and to the composition of their classrooms. We do not know, however, whether the observed variations in use were "caused" by differences in academic training; by the needs of students; by the common educational prescriptions providing highly structured, basic-skills instruction for low-achieving students and conceptually stimulating, less-structured instruction for high-achieving students; by some other factor not measured in the study; or by some combination of all of these.

Before deriving any hasty policy implications, we further analyzed these data, taking into account the relationships among the teacher characteristics and classroom context variables. For example, those classrooms with a high percentage of minority students were also those with students of lower ability. Thus, we examined how percentage minority, ability level, grade level, courseware knowledge, and subject-matter knowledge (including percentage of coursework in science, social science, and mathematics) together accounted for cluster membership. Results indicate that, indeed, teachers in the drill-and-practice cluster had significantly more undergraduate coursework in science and a significantly higher percentage of minority students than teachers in the other three clusters. In addition, teachers in the orchestration cluster were distinguished by less undergraduate coursework in science, greater courseware knowledge (as rated by interviewers), and classrooms with fewer minority students. Finally, teachers in the enrichment cluster had less undergraduate coursework in science than did teachers in the adjunct-instruction cluster.

We conclude, then, that there is good reason for concern regarding social inequities in computer-based instruction. Minority students are more likely than other students to receive computer-based instruction with drill-and-practice programs. And for reasons not clear to us, minorities tend to be taught by teachers who have more extensive undergraduate backgrounds in science.

The causal links between teacher characteristics, classroom contexts, and microcomputer-based instruction cannot be disentangled in our data. What we have observed, however, follows from current educational prescriptions of direct instruction in basic skills for low-achieving students. Perhaps, as this prescription implies, the microcomputer-based instruction received by minority students is appropriate; research that shows a positive relation between drill and practice and achievement lends credence to this prescription (e.g., Kulik, Kulik, and Cohen, 1980; Kulik, Bangert, and Williams, 1983; Ragosta, 1983). But what if the medium is the message? Then minority students are more likely to be constrained in their knowledge of microcomputers than are other students. Moreover, what if the prescription is inaccurate? Such prescriptions might significantly reduce the probability of finding other instructional modes (e.g., simulations, microworlds) that improve the achievement of low-achieving or minority students (e.g., Borko, Shavelson, and Stern, 1981; Glaser, 1984).

These findings, then, call into question current educational policy and practice. For example, perhaps science teachers should not be the primary source of leaders in the educational technology revolution. According to our data, if a balance in the nature of microcomputer-based instruction is sought, teachers with backgrounds in the social sciences might be important participants. But our data do not permit us to disentangle curricular background of teachers from the composition of their classrooms. Perhaps, then, the current emphasis on basic-skills instruction should be called into question for leading to too narrow a definition of the nature of computer-based instruction. What would happen if conceptual understandings were given greater emphasis and basic skills less emphasis, since there is reason to believe that a complete repertoire of basic skills is not necessary for conceptual understanding? Would a chain of instructional prescriptions change with corresponding improvement in student motivation and achievement, or would student behavior problems increase and achievement drop? We do not have answers to these questions, but research that bears on them should be high on any educational research agenda.

RECOMMENDATIONS FOR STAFF DEVELOPMENT IN MICROCOMPUTER-BASED INSTRUCTION

By considering the literature on staff development, case studies of staff development for microcomputer-based instruction, teacher surveys, recommendations and admonitions obtained from the 60 microcomputer-using teachers in our study, and our observations, a set of recommendations was derived for staff development in microcomputer-based instruction. Many recommendations have already been incorporated into staff development programs; others are rarely included. Many might be implemented in more than one way, reflecting, in part, district philosophy and resources. Accordingly, these recommendations are not strict prescriptions for staff development programs. Planners need to consider the recommendations and design staff development activities that best meet their needs and resource constraints.

Recommendations for the Content of Staff Development

A basic staff development course should include the following topics: operation of the microcomputer, selection and evaluation of courseware, instructional uses of microcomputers, computer literacy, and methods for integrating microcomputers with the ongoing curriculum. This course might also include computer programming, at least to the degree that programming either helps teachers understand how the computer operates or meets teachers' particular needs.

Operation of the Microcomputer. Teachers should receive hands-on instruction in the operation of the microcomputer. As a consequence, they should be able to start the computer, load and run programs, keyboard, and troubleshoot minor hardware and software problems.

Selection and Evaluation of Courseware. Teachers should review a wide range of courseware that is appropriate for their subject area and grade level, much of which should be immediately available for their use. This review would include application of evaluation criteria and selection of high-quality courseware based on the evaluation. Courseware evaluation forms might be developed by teachers and district staff with expert consultation, or evaluation guides might be adopted from those in the published literature (see Shavelson et al., 1984).

Instructional Uses of Microcomputers. Microcomputer-based instruction involves more than just questions and answers delivered by a program on tape or disk. Teachers should be exposed to a wide variety of roles the computer can play. These roles include its instructional use as a tool for analyzing data or simulating the effect of changing parameter values in an experiment, as a tutee to be taught by students writing or using simple programs (cf. Taylor, 1980), or as a simulated environment ("microworld") for the student to explore.

Computer Literacy. Teachers recommended that an initial training curriculum include computer "literacy." By this they meant instruction on the history of the development and uses of the computer, and on issues such as equity, ethics, and social impact.

Integration of Computers with Instruction. A critical element of staff development, and one that we saw most lacking in our study, is training on how to integrate microcomputer-based instruction with the subject matter and classroom activities. Simple logistical procedures should be considered, such as rules for student use, transitions between computer and non-computer activities, and grouping strategies. More important, teachers need guidance in planning how to match courseware to their instructional goals, the structure of the subject matter, the nature of the students, and the content of instruction. These decisions and instructional practices, of course, constitute part of what teachers do every day, whether or not they use a computer. Computers, however, introduce an additional order of complexity to teaching.

Integration involves not only the use of microcomputers as learning activities within the ongoing curriculum, but it also involves the adaptation of the curriculum to important software packages (e.g., Logo, the "Koala Pad" for drawing). Lesson plans, introductions to the lesson, ways to get students to transfer what they are learning, and methods for monitoring and evaluating microcomputer-based learning activities must be developed sensibly to integrate a new piece of software into the curriculum. Teachers need to be trained to do this as well.

Computer Programming. We recommend that computer programming be included in introductory staff development to the extent that such knowledge is needed to understand how the computer works and to understand the basis for applying the other skills recommended above, such as troubleshooting computer operation. This means that some programming will be an essential part of training, but perhaps to a much lesser extent than many non-teachers would like.

The depth to which programming is taught in an introductory course will depend, in large part, on the extent to which teachers need to know how to program in order to use the microcomputer instructionally. We suspect that mathematics teachers, both elementary and secondary, will need more extensive introductory training in programming than most others because simple programs can be written as tools for solving mathematics problems. We have excluded science teachers, for example, because we suspect that the more complex data analysis programs or simulations often used are too time-consuming for students or teachers to develop as part of the regular science course. However, this decision must, ultimately, be made locally.

Recommendations for the Organization of Staff Development

A conceptual framework derived from the work of Fenstermacher and Berliner (1983) provides one way to appraise the value of the organizational features of staff development, both for those activities planned ("forward-looking evaluation") and those activities that have already taken place ("backward-looking evaluation"). The framework, when applied for evaluative purposes, includes matching a staff development activity against a definition of staff development, a set of organizational features, and the specific conditions that are expected to contribute to the merit, worth, and success of the activity. Our application of this framework as well as data reported in the literature and collected from our sample of teachers led to the recommendations briefly summarized here. (For details, see Shavelson et al., 1984.)

Initiation of staff development activities should be a collaborative effort of teachers and administrators. This links financial decisions to the needs and experiences of teachers implementing microcomputer-based instruction. Collaborating teachers provide added support for one another. We recommend that *participation* in staff development activities be voluntary. Voluntary participation is expected to increase teachers' commitment to microcomputer-based instruction and their willingness to spend the time and energy needed to acquire essential knowledge and skills.

The *objectives* of a staff development activity should be clearly stated to both providers and participants; indeed, both parties should have input into the definition of objectives. These objectives would reflect both teachers' needs and district goals for microcomputer-based instruction. The content of staff development activities should be clear and concrete, employing courseware that is immediately applicable to the teachers' instructional needs.

A *variability* condition in the framework leads to the recommendation that the staff development activity permit teachers to decide on the nature of their participation. Teachers recommended a number of ways this might be accomplished. One way is to individualize instruction as much as possible. For example, each workshop might focus on a different topic requiring different levels of expertise. The workshops would range from introductory core courses to courses in advanced programming.

The ideal *instructor* would be someone who is or has been a teacher with extensive experience in microcomputer-based instruction in the classroom and laboratory. He or she should be an expert on computers and instructional uses of them, and should be competent in teaching adults. The instructor should be viewed as competent by participants, but not "too technical" or out of touch with students.

The *duration* of the staff development program should be sufficiently long to permit teachers to learn, practice, master, and apply the skills imparted. Although the actual time will vary according to the design of the program, our observations and the literature suggest that relatively little time has been devoted to introductory activities—typically 8 to 10 hours spread over three or four sessions. Although this may be sufficient to show teachers how to operate the machine and superficially review some courseware, it often falls short of meeting the duration requirement and usually does not include other important topics, such as integrating the microcomputer into instruction.

The *maintenance* condition of the framework leads to the recommendation that staff development activities be followed up during the period in which teachers apply the newly acquired skills in their classrooms or laboratories. During follow up, teachers need a variety of support services or expert resources to assist with hardware repair; with evaluation, selection, and modification of courseware; and with day-to-day troubleshooting. At the very least, teacher networks might be formed to exchange ideas and experiences throughout implementation of microcomputer-based instruction.

Incentives should be provided in all phases of staff development to support and encourage microcomputer-based instruction. However, our results suggest that most teachers nominated as successful in microcomputer-based instruction participate in staff development activities for reasons other than incentives. One reason was their high level of interest in and commitment to microcomputer-based instruction. Another was that many of these teachers had attained maximum salary levels. A third reason was that such inducements might prompt teachers to participate for the wrong reason.

These findings do not imply the absence of incentives. On the contrary, they suggest that the *types of incentives* offered need to be given careful consideration. Release time and, to a much lesser extent, salary credits were standard incentives for staff development in our study. For many teachers, time was more valuable than money. They had many more ideas about how to use computers than they had time to put them into practice. This suggests that time, rather than monetary rewards, might be the major factor in supporting and encouraging successful microcomputer-based instruction.

RECOMMENDATIONS FOR COURSEWARE DEVELOPMENT

We used teachers' recommendations, along with a review of literature and published evaluative criteria, to formulate recommendations for the design and development of courseware (see Shavelson et al., 1984). Some of the recommendations already influence courseware design (e.g., Walker and Hess, 1984), but much progress can still be made to make courseware more teacher-friendly.

Pedagogical Attributes of Courseware and Teachers' Roles in Its Design

Courseware with substantial pedagogical value might well result if teachers play an expanded role in its design and development because they possess expert, clinical knowledge of teaching and learning. Along with computer experts and others, teachers should be involved in the development of courseware instructions, documentation, and ancillary materials, to ensure that these materials are sufficiently simple and unobtrusive that they do not distract from the pedagogical goals of the program. A minimum criterion for simplicity is that the rules for using the courseware be simpler to learn than the skills being taught by the program. This may be achieved by implementing the teachers' recommendations relating to courseware friendliness. Furthermore, teachers are in a position to ensure that the activities involved in the pedagogical task, governed by these rules, bear directly on the knowledge and skills to be imparted.

We recommend that teachers play a role in identifying prerequisites to the concepts and skills to be taught, as well as alternative, appropriate methods for communicating the subject matter (e.g., tutorials, simulations). They could help assure that the courseware content contains substance and is error-free; the courseware engages appropriate thinking and problem-solving skills; the level, pace, and presentation are proper for the intended audience; and students actively engage the subject matter presented in the program. Because they are aware of common misconceptions held by students and possible didactic paths for correcting them, teachers might help determine how the courseware will provide diagnostics and feedback. Finally, because teachers are familiar with curricula in their subject-matter areas, they might assist in coordinating courseware with other curricular materials.

Evaluation and Revision

During its development, instructional software should be evaluated and modified continually until it satisfies the design criteria set for it. Several evaluation and development cycles will help identify procedural and conceptual problems students encounter while interacting with the program, and problems encountered with program-generated instructions, "help" facilities, and documentation. Similarly, testing the program with multiple audiences (students, teachers, subject-matter experts) should uncover flaws and significantly decrease the probability of the program crashing. The evaluation and revision cycles also provide a cross-check of the courseware's curricular relevance, potential for modifiability, and subject-matter accuracy.

Strategy for System Design

We recommend that courseware design and development be carried out by a team, not individually. This team would include teachers, subject-matter experts, behavioral scientists, and programmers. In addition to the courseware's subject-matter and pedagogical attributes, the design process should include the development of general utilities applicable to many programs (e.g., input and output formats, error diagnostics), strategies for program writing ("coding") that use the computer's capabilities fully, and, as recommended above, evaluation and revision cycles.

Reviewing and Copying Courseware

We are not in a position to recommend policies regarding reviewing and copying courseware with its legal ramifications. However, to respond to teachers' needs for courseware examination and evaluation, the concept of "courseware libraries" has much to offer. Such libraries might be set up by publishers, state education agencies, or districts. They would permit teachers, in person or via telecommunications, to review courseware, its documentation, and other teachers' (and computer specialists') evaluations of the courseware. The library concept seems to have merit in that courseware could be made widely available for teachers to review while protecting the publisher's copyright.

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